were pregnant, suggesting that in humans, potentially the most vulnerable groups—young males and women of childbearing age—are being exposed with the greatest frequency.

Predictably, the Calorie Control Council (CCC), a beverage industry trade group, assailed these findings. "The NAS dismissed the significance of studies that illustrate differences in saccharin exposure at high doses," complained Robert Gelardi, a CCC spokesman. "Also, they failed to use more reliable data on consumption that we supplied, which showed that fewer children are exposed to saccharin than the NAS said." Asked whether the CCC agreed, however, with the basic conclusion of the NAS report—that saccharin poses a potential risk of cancer to humans—Gelardi said, "in a lay sense, we disagree. In a technical sense, we acknowledge that many different substances pose a risk of cancer to humans." In the case of saccharin, he said, "the safety is evident and—as confirmed by the NAS report—the risks are hypothetical."

### Lack of Benefits Data

The FDA, just as predictably, has taken the opposite tack, calling the NAS report comprehensive, objective, and thoughtful, and pulling out of it those parts that best support its own opinion. "It is particularly significant that the NAS scientists expressed concern about the exposure of children and women of childbearing age to saccharin," said FDA Commissioner Donald Kennedy, "and concluded that there are no demonstrated benefits from the use of this artificial sweetener." This last point is particularly masterful phrasing, because what the NAS concluded was that no good studies exist that demonstrate either health benefits or a lack of health benefits from saccharin use, whether by diabetics, the obese, or in foods, drugs, or toothpaste. (The risk from exposure to the amounts of saccharin in drugs and toothpaste is so small, the panel said, that the existence of any benefits may justify its use in them.) The panel did note, and the CCC emphasized in its comments, that many physicians *believe* that saccharin is useful for obese and diabetic patients. Attempts should be made to either confirm or disprove this belief, the panel recommended. Initially, the panel was inclined to state bluntly that no benefits existed, but members said that as the report proceeded through drafts the conclusions were toned down to read "there are no studies that permit an objective assessment of asserted health benefits."

Despite the absence of data on benefits, or perhaps because of it, those who support the use of saccharin are clinging to the fact that people think it is good. The American Diabetes Association (ADA), for example, responded to the NAS report on 6 November with a statement that "We believe that much subjective good from the use of nonnutritive sweeteners does accrue to those diabetic people who must avoid sugar and other sweets." At this time, the ADA continued, "we plan no change in our advice on the use of saccharin by diabetic persons . . . [and see] little justification for placing further restrictions on the use of saccharin by the American public." Ronald Kalkoff, an endocrinologist who chairs the ADA panel on saccharin and who also sat on the NAS panel, said that he did not think the NAS report and the ADA statement were contradictory. "When compared with the risks from cigarettes, coffee drinking, or other common habits, the risk from saccharin is very small," Kalkoff said. "And it does affect the quality of life for diabetics, particularly teenagers who get peer pressure to consume common foods."

It thus seems that after this round, at least, those who support either the industry or the FDA position are standing easily in their own corners. Each side is now awaiting not only the second NAS report but also the results of an epidemiological study of bladder cancer victims now being conducted by the FDA and the National Cancer Institute—awaiting the possibility that either report will deliver a knockout punch to the other side. "As it was before, we had to contend with a well-financed industry lobby against a divided scientific community, and that hasn't really changed," said one Senate staffer. "If we had to vote today, the chance of getting the congressional bar on the FDA ban lifted is still slim."

—R. JEFFREY SMITH

# Librarian Turned Entrepreneur Makes Millions Off Mere Footnotes

In the spring of 1953, while working at Johns Hopkins University as an assistant librarian for an indexing project, Eugene Garfield, 27, noticed that the references at the end of a scientific paper might do more than merely acknowledge the work of another researcher. It was not long before Garfield came up with an idea for a special kind of library index. The upshot of his vision, however, has been anything but academic.

He now heads an information empire founded on the lowly footnote. He is also a millionaire.

Garfield, the man who brings you *Science Citation Index* and *Current Contents*, is the president and chairman of the board of the Institute for Scientific Information (ISI), the world's first multimillion dollar corporation to be based on providing access to scientific literature. Today the Philadelphia-based company employs more than 470 people, has offices in nine countries, has two Nobel Laureates on its board (Joshua Lederberg and Harold C. Urey), publishes three different citation indexes, and, despite predictions of financial doom when Garfield first launched the *Science Citation Index*, now has total sales of more than $15 million a year (with Garfield owning 65 percent of ISI's stock).

Though it markets more than 20 information-related services, ISI is perhaps best known for its six editions of *Current Contents* (about 40 percent of ISI's annual sales), which reproduce the contents pages from more than 5200 journals in 31 languages. Each edition is published weekly and the subscription cost is $135 per year. All together, the six editions of *Current Contents* are estimated to be read by more than 300,000 scientists. But the financial and conceptual backbone of the organization are its three indexes (about 48 percent of ISI's sales), the *Science Citation Index* (SCI), the *Social Sciences Citation Index* (SSCI), and the newly launched *Arts and Humanities Citation Index*. The SCI, for example, culls footnotes from more than 2600 scientific journals, allowing researchers to identify topic relationships missed by subject indexes and also to


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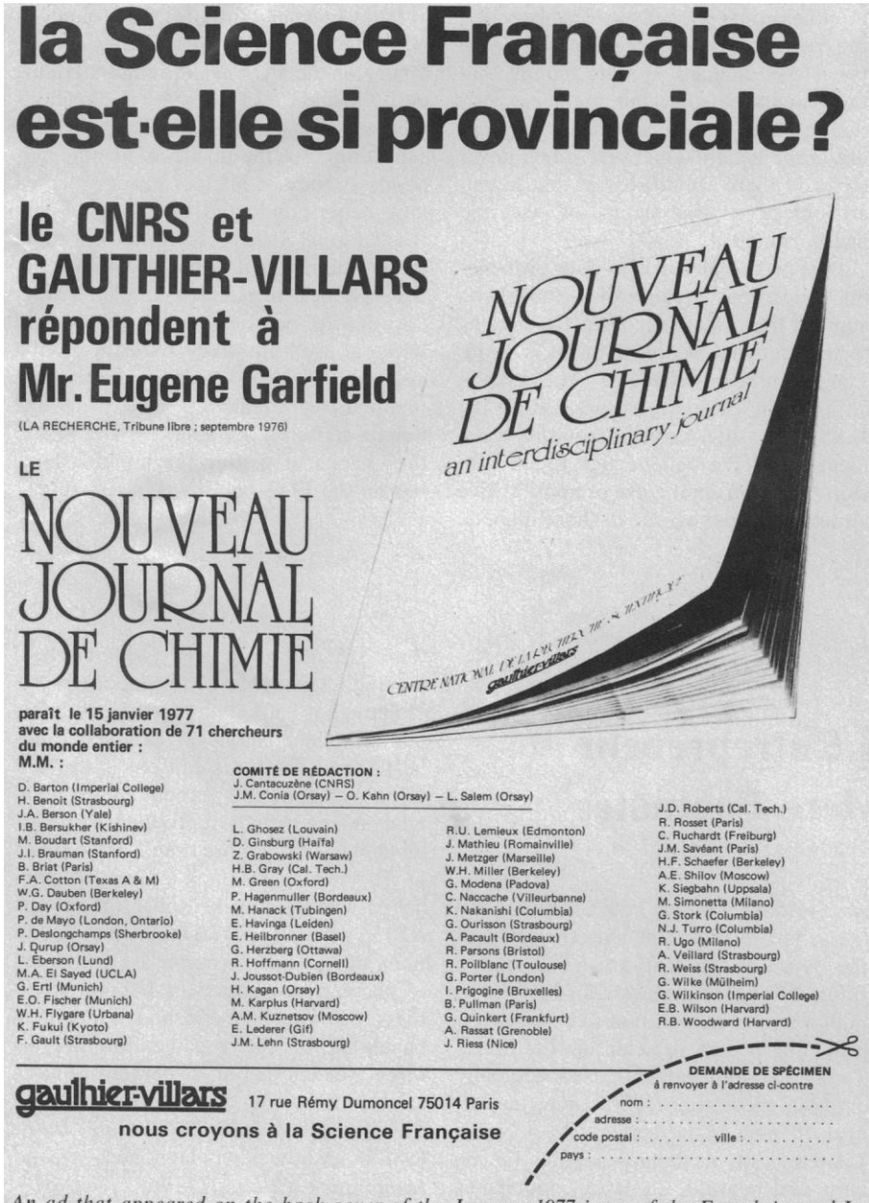
search forward in time through a given body of literature. The 13 thick volumes of the annual SCI sell for a steep $3200 and thus for the most part are found in libraries (more than 1000 of them). Its influence, however, ranges far indeed.

Take citation analysis, the most controversial of Garfield's spin-offs. As early as 1955 Garfield was saying in the pages of *Science* (15 July 1955, p. 108) that a citation index could also "evaluate the significance of a particular work and its impact on the literature and thinking of the period." The method assumes that the number of citations to a particular paper reflect its significance or impact, with the basic information about who cites whom being readily obtainable from the pages of the SCI. Under each scientist's name appear the titles of his cited articles and of the articles citing them during a given period. Such lists may sound dull, but their impact has been profound. Citation analysis now helps to shape U.S. science policy (through the National Science Foundation's *Science Indicators*), to locate scientific specialties ripe for a new journal, to critique an entire country's research effort, to help decide the outcome of promotion and tenure debates, and to raise hue and cry from those who either dispute its validity or resent the power that citation analysis seems to hold over them.

A less controversial application of Garfield's methods involves looking at how often journals, rather than individuals, are cited and how often they cite one another. He has been refining the technique since the early 1970's—with interesting results. For instance, a paper by Garfield in *Science* (3 November 1972, p. 471) looked at 2400 journals, containing a total of 10 million scientific papers, which were cited some 27 million times, and distilled the numerical chaos into a bitter pill: half of all the citations came from a mere 152 journals. At the top of the citation heap was the *Journal of the American Chemical Society*, with the *Physical Review* and the *Journal of Biological Chemistry* taking second and third places. *Nature*, fourth, nosed out *Science*, seventh. *Lancet*, eleventh, was far ahead of the *New England Journal of Medicine*, twenty-fifth, and the *Journal of the American Medical Association*, twenty-sixth. Said a wry editorialist reviewing the study for the *New Scientist*: "Henceforth, academic interviewees, it won't be: How many papers have you published? but: Where? Publish at the *top* or be damned."

Taking on an even bigger project, Garfield has set ISI's computer, an IBM 370-148, to evaluate the citation relationships between countries. In the case of France, the technique even aided in the birth of a journal. Garfield fused the 129 French journals from the Institute's data banks into one statistical entity and found that French journals cite foreign journals much more often than their own, while their own are mainly cited by themselves. The results were published, in French, under the title *Is French Science Too Provincial?* in the French journal *La Recherche*. In the article, Garfield concluded not only that French science was "in decline" but that "scientists risk oblivion when they avoid the reality of English as the international language of science."

The reaction, needless to say, was intense. French scientists denounced the article as "pernicious" and "scurrilous." One accused Garfield of "linguistic imperialism." A former Prime Minister of France (1959 to 1962), Michel Debré, entered the fray and warned of "a national revolt which could become, or rather will become, the natural attitude of young researchers if we follow Garfield." Another reaction, however, appeared in a full-page advertisement (at left) on the back cover of the January 1977 issue of *La Recherche*, announcing the launch of a new journal, *Nouveau Journal de Chimie*, to be published mainly in English and to have an international board of editors.




*An ad that appeared on the back cover of the January 1977 issue of the French journal* La Recherche. *It reads as follows: "Is French science too provincial? The French National Center for Scientific Research [CNRS] and Gauthier-Villars [publishers] respond to Mr. Eugene Garfield. The* New Journal of Chemistry *will appear January 15, 1977 with the collaboration of 71 international scientists." And at the very bottom of the ad: "We believe in French Science."*

Garfield's infatuation with lists surfaced while he was still in grade school. After classes, when he was not making deliveries for his uncle's Greenwich Village liquor store or busy picking up business skills as a clerk in the New York City garment district, Garfield roamed the High Bridge branch of the New York Public Library, across from his home in the West Bronx. Having glanced at every book by the time he graduated, he impressed people as being very well informed for his age. "But I never really read them," Garfield told *Science* during a recent interview. "I just knew the titles, kind of like people do with *Current Contents*."

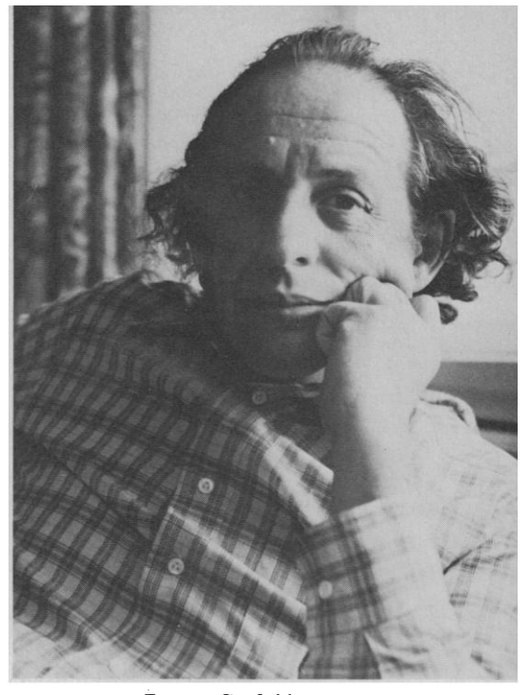
The path to indexing was anything but straightforward. After high school Garfield wandered, for a while welding in a shipyard, then studying engineering, then doing construction work in Colorado, and finally serving with the U.S. ski troops after the draft caught up with him in 1943. The war over, Garfield started on a chemistry degree at Columbia University. Moonlighting as a New York City cab driver, he paged through texts while in his Checker and won the title of "professor" from his fellow hackies. "In spite of this dubious distinction," he later wrote, "I was welcomed into the invisible college of cab drivers located at the Horn and Hardart Automat Cafeteria at 57th Street and 7th Avenue. Seminars were usually held at 3:00 a.m. to discuss such burning topics as the 5th race at Hialeah, Babe Ruth's 1924 batting average, or the upcoming All-Star football game. In those days I was not discussing how to forecast Nobel Prize winners."

With his degree came a lab job at Columbia University that ironically cut short his career in chemistry. Struggling to prepare some picric acid derivatives, he instead produced a minor explosion. A second attempt—and a second, more severe explosion—set Garfield dreaming about putting a closet full of already prepared chemicals in the lab to good use. The closet was in disarray, however. All it needed was a little organizing. "I said what the hell, why should I be breaking my back doing all this, when somebody's already done it before? We could have saved days and days of work, not to mention explosions, but there wasn't a decent system of indexing."

But before Garfield could put a chemical filing system to work in the lab, a less life-threatening career unexpectedly appeared. Out of curiosity, Garfield attended a session on documentation at the Diamond Jubilee meeting of the American Chemical Society, and by chance heard about an opening at a medical indexing project at the Johns Hopkins Welch Medical Library. He couldn't pass it up. Both Garfield and his boss at Columbia, Professor Louis P. Hammett, agreed that Garfield had neither the aptitude nor motivation for lab work, and Hammett recommended Garfield to his new employer as a hard, "but not very original worker." Time proved him wrong.

At Johns Hopkins, Garfield was put to work looking for new ways to index scientific literature and soon realized that nearly every statement made in a review article was supported by a reference to a previous piece of literature, and that the bibliography of each of these articles was really a series of indexing statements. Though the project made some use of the idea, it mostly played in the back of Garfield's mind. By 1953 Garfield had organized at Johns Hopkins the first symposium on machine methods in scientific documentation, which drew 300 people and considerable press coverage. A wire service story on the meeting was read by William C. Adair, a retired vice president of the company that publishes *Shepards Citations*, a legal reference tool that has been listing case citations for lawyers for more than a century. He wrote Garfield about the possibility of using something like *Shepards* for indexing scientific literature. Garfield was intrigued. He went down to the Enoch Pratt library in Baltimore and looked at a copy of *Shepards*. "It was a eureka experience," Garfield recalls. "That was a supreme moment in my career. I don't know if I screamed. I'm sure I said something, and from that point on I knew exactly what I had to do."

Garfield quit the indexing project, took an M.S. in library science from Columbia (1954), published a paper in *Science* (15 July 1955) entitled *Citation Indexing for Science*, and started work on a Ph.D. in structural linguistics at the University of Pennsylvania. And business ventures kept rising to the fore. In 1958, to help finance his degree work, Garfield rented a Xerox plate maker and a Davidson small offset press and started printing loose-leaf pages of *Current Contents/Life Sciences* in a "converted chicken coop." By 1961 Garfield had his doctorate and a small company, the Institute for Scientific Information, which published *Current Contents* and *Index Chemicus*, a system for registering all articles that reported new chemical compounds. That year, ISI received a grant from the National Institutes of Health, later transferred to the National Science Foundation, to produce a pilot citation index of the genetics literature and to study the feasibility of a citation index to all science literature. The study done and the genetics index published, Garfield called for the trial of a multidisciplinary index. NSF said no, it had no future, and Garfield, not about to be snubbed by an agency, decided to go it alone.



*Eugene Garfield*

### Moving Up

That decision has obviously paid off. Today the ISI information empire is not only healthy, it is growing, as *Science* found out during a recent visit to Philadelphia. Under a clear blue sky on 17 October, Garfield drove a silver shovel into the mud of a construction site in Philadelphia's University City Science Center, breaking ground for a $6.5 million ISI International Headquarters. To be finished next fall, it will have a day-care center and will expand to hold up to 1000 employees. Said Garfield at the ceremony: "And we think we are going to need them in the relatively near future."

Not everyone is happy about it, however. The sheer size of ISI and the lack of any worthy competition makes for an unusual concentration of power that some critics find alarming. ISI's *Social Science Citation Index*, for instance, now lists 3900 journals—out of some 50,000 scientific journals in the world. Though getting everybody's favorite in the index is economically impossible, some critics contend that the SSCI exhibits a built-in bias. As Jon Wiener put it in the fall 1974 issue of *Dissent*: "Among the 3200 indexed journals [listed in 1974], selective coverage is given to such unlikely titles as *Mosquito News*, *Soap/Cosmetics*, *Digestion*, and the *Tas-*

*manian Journal of Agriculture*, but there is no coverage at all of journals like the *Review of Radical Political Economy*, *Radical America*, *Socialist Revolution*, *Telos*, *Insurgent Sociologist*, *Working Papers for a New Society*, or *Monthly Review*, to name a few."

And the upshot of not being listed in an ISI information service can be quite concrete. Being dropped from a *Current Contents* listing has contributed to the demise of several small journals. And, on the other hand, being listed can bring a researcher a gratifying, but unmanageable number of reprint requests. E. F. Hartree, a biochemist at Cambridge University in England, wrote an article in *Analytical Biochemistry* describing a modification of a widely used method for determining protein concentrations. Due to slight differences in his address as listed in the article and as listed in *Current Contents*, he was able to tell the requests apart. The original article drew some 375 reprint requests. The *Current Contents* listing drew 2125.

A subtle pressure to conform also lurks within the pages of the *Science Citation Index*, according to Garfield. "The amusing thing about the business of citing," he says, "is that in the old days people used to say citation indexing wouldn't work because people didn't cite the right people. Now, as it turns out, if you don't cite the right people, your papers will not be retrieved, and thus not cited in the future."

Critics, however, see citation "self awareness" leading to potentially absurd ends. One irate researcher, writing in the letters section of *Science*, noted that for best results it would be wise to "cite yourself as often as possible; insist that your work be cited in all articles that you review; and automatically pass articles that already contain a sufficient number of citations to you. Unfortunately, you will not get any credit if an author leaves out one of your initials, or, even worse, misspells your name. Nevertheless, if the above steps are taken, you should be able to push your 'lifetime citation rate' over those of any immediate rivals. If all else fails, publish a paper containing a subtle misuse of the second law of thermodynamics."

Citation counting has taken other hard raps from critics over the years. The SCI, they note, lists only first authors, even though joint authorships have been on the rise for the past 20 years, to the point in certain areas of physics that a single paper will have 20 to 70 authors. In response, Garfield has published a list of the 300 most-cited authors, including secondary authors. But even this list is an ambiguous indicator of scientific quality. It, for example, did not contain the name of *any* of the most recent Nobel Prize winners. Not all good research is cited, the critics note. They point to fundamental papers that were ahead of their time and were ignored before their importance was realized. And, on the other hand, they point to cases of "obliteration," where the work that everybody knows is often not cited.

Such criticisms have taken their toll. Over the years Garfield has urged caution in the use of citation analysis, but the warnings of late have become more frequent and urgent. An editorial in a September 1977 *Current Contents* speaks of "massive" qualifications and warns that in citation studies "it is wise to take little or nothing for granted."

In the interest of clearing up some of the issues, Garfield has started publishing a "citation classics" column in *Current Contents*. Though many of the papers show positive citing patterns, that is, a good piece of research being cited over and over, Garfield has also had the foresight to print some of the exceptions. Take the case of Arthur Jensen. His paper appeared in the 1969 *Harvard Educational Review* and took an extreme genetic view of the IQ controversy. According to Garfield's search through the SCI computer tapes, the paper was cited 638 times between 1969 and 1977 (an extraordinary number compared to the 1.7 times the average paper is cited). Yet Garfield found that only 25 percent of the citations were to articles in agreement with Jensen's positions.

Garfield, during an interview with *Science*, admitted that the citation controversy has taken a financial toll as well. "If anything, we've lost business through citation analysis," he said. "There've been institutions that held up their subscriptions to the SCI because some particular scientist at that institution thought it was a vainglorious exercise and that they didn't need that sort of thing around."

### Eyeing the Future

It is clear, however, that despite any number of controversies, ISI has achieved solid financial footing in the past few years, and that fact has given Garfield the freedom to toy with some other projects. Extending the SCI back to 1900, for use as a historical and sociological tool (it now goes back to 1961), has long been a dream of Garfield's that is now getting a serious airing in the corporate boardroom. The Institute recently came out with its third index, the *Arts and Humanities Citation Index*, and in 1979 will introduce an arts and humanities edition of *Current Contents*. Also, next year, ISI Press will come out with a *Transliterated Russian-English Dictionary*, a project that grew out of a Garfield whim. Garfield is also looking to the electronic future. The British Post Office, which also operates that country's telephone service, is currently test marketing a modified TV called Prestel (*Science*, 7 July, p. 33). A subscriber picks up the phone, dials a central computer, and the TV screen comes alive with breaking news from Reuters, the latest action on the stock market, weather reports, a mail-order catalog, or tips on the best French restaurants in London—all at the touch of a button. And ISI is there as well, supplying the system with SCITEL, a science news service in popular format.

For Garfield, the information entrepreneur, the trip to the top has not been without its reversals and slumps. For 8 years *Current Contents/Social Sciences* floundered and finally disappeared. Only recently has it been revived. At one point there was a *Current Contents* educational edition, but it too died for lack of interest. Garfield has had not only duds but a few fizzles as well. ISI operates a custom computer service that scans literature from a particular customer's angle. A science news agency at a large university, for example, might regularly get a readout of articles recently published by its own researchers. But according to Garfield, the service never caught on. "It takes more than a few hundred users to make something like that a huge success," he says. But a few flops certainly haven't diminished Garfield's creativity. As one ISI executive put it: "The board just sits there and tries to throw out his wilder ideas. But new ones seem to keep popping up."

One gauge of Garfield's interests can be gained by paging through his *Essays of an Information Scientist*, a two-volume set of editorials collected from successive issues of *Current Contents* and published last year by ISI Press. There are not only forays into such topics as copyrights, reprint exchanges, citation analysis, and journal citation studies but short vignettes on jazz transcriptions, the changing doctor-patient relationship brought on by growing biomedical literacy, smoking, and the literature on tickling. His interest in citation indexing and analysis, however, is always the central focus. To some, it borders on being compulsive. A researcher from Aslib, an international library association based in England, recalled that on one occasion Garfield went "to a great deal of

trouble to reach some obscure corner of London" in order to hear a rock group called "The Citations."

Some critics feel that this intense preoccupation with the stuff of citations belies a drive for the corporate dollar, of which Garfield has quite a few at stake. As one reviewer of his *Essays* put it, "Garfield promotes his products; Garfield announces his plans for editorial change; Garfield evaluates his products for the information community; Garfield introduces his associates and vouches for their character and integrity; Garfield acknowledges the adulation his publications have received among users. Garfield's gross is his intense preoccupation with his corporate welfare. It is never so labeled, but no label is needed."

But it is, after all, Garfield's corporate self-interest, coupled with his subtle insights into the information needs of the scientific community, that has put such revolutionary tools into the hands of scientists around the globe. And, as *Science* found in Philadelphia, the craving for corporate growth has not been at the expense of a certain style. The company's fleet of chauffeur-driven cars, for example, includes a Cadillac, a Lincoln, a Jaguar, and, until 2 years ago, at which point Garfield gave it to his son, a Checker.

—WILLIAM J. BROAD

*Erratum*: In the report "Children absorb tris-BP flame retardant from sleepwear: urine contains the mutagenic metabolite, 2-3-dibromopropanol" by A. Blum *et al.* (15 September 1978, p. 1020), the unit of measure for dibromopropanol in Table 1, column 3, should have been nanograms, rather than milligrams, per milliliter. In reference 28, sentence 2, the word "sells" should have been "formerly sold." We apologize for this error to Apex Chemical Company, Inc., which discontinued sale of Fyrol flame retardant, for use in children's sleepwear.

**RESEARCH NEWS**

# Computer Science: Surprisingly Fast Algorithms

Mathematicians have traditionally been more concerned with showing that solutions to problems exist than with determining what the solutions are. The advent of the computer changed this situation by making it possible to at least think about computing solutions to complex problems. But it has become increasingly clear that there is a big difference between a solution that can be computed in theory and one that can be computed in practice. Often the straightforward way of solving a problem involves so many operations that, even for moderately sized problems, the solution is effectively noncomputable.

From this concern with finding computable solutions to problems came the idea of developing "fast" algorithms that require fewer steps than those currently in use. The payoffs from fast algorithms can be enormous. For example, the development of the fast Fourier transform (FFT) completely changed whole areas of science, such as crystallography, by making possible computations that were previously infeasible. Similarly, entire issues of engineering journals have been devoted to applications of the FFT.

Recently, computer scientists have discovered new fast algorithms for manipulating polynomials and power series. (A polynomial is an expression of the form $a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n$, where the $a$'s are constants. The integer $n$ is the "degree" of the polynomial. A power series is a polynomial extended to include an infinite number of terms.) Since operations on power series are so common, the new algorithms could be of great practical importance.

The new algorithms are also interesting from a mathematical point of view. According to Alan Borodin of the University of Toronto, they are completely nonintuitive and so are "very, very surprising." For example, one result is that any power of a polynomial can be computed as quickly as squaring the polynomial.

Discoveries of these fast algorithms began in 1972, when M. Sieveking of the University of Zurich found a new, rapid way to compute the first $N$ terms of the reciprocal of a power series. Then H. T. Kung of Carnegie-Mellon University noticed that Sieveking's method is actually a well-known procedure called Newton iteration. Shortly after Kung made this observation, John Lipson of the University of Toronto and, independently, Kung and Joseph Traub of Carnegie-Mellon determined that Newton iteration can be applied to solve power series equations, thus leading to a number of fast algorithms.

The idea behind Newton iteration is to approximate the power series solution to a particular equation with a polynomial consisting of the initial terms of the power series that is the actual solution. At each step of the Newton iteration, more terms are added to the polynomial approximation. Traub explains that when Newton iteration is applied to power series equations, the iteration always converges and the number of correct terms at least doubles at each step.

Using Newton iteration, Kung showed that the first $N$ terms of the reciprocal of a power series can be computed as quickly as multiplying two $N$th degree polynomials. The fastest known method for polynomial multiplication is the FFT, which requires $N \log N$ operations.

Dividing a power series by a power series can be thought of as a multiplication problem in which one power series is multiplied by the reciprocal of another. When division is represented in this way, Kung's result about reciprocals leads to the conclusion that the first $N$ terms of the quotient of two power series can be computed in no more than $N \log N$ steps. Thus division is no harder than multiplication.

Kung and Traub recently generalized the result about power series to apply to all algebraic functions, including such complicated functions as the reciprocal of a power series. These algebraic functions, which arise in many areas of mathematics, are the solutions of polynomial equations in which the coefficients of the variables are themselves polynomials. The textbook method of computing algebraic functions is by comparison of coefficients—a method that can be extremely slow. For example, if the algebraic function satisfies a polynomial of degree $n$, computation of the first $N$ terms of the polynomial by comparison of coefficients requires as many as $N^n$ operations. With new algorithms, the first $N$ terms of any algebraic function can be computed with the same number of operations that are needed to multiply two $N$th degree polynomials, or $N \log N$. They established this result by showing that the first $N$ terms of any "regular" algebraic function can be computed rapidly by iteration. (A regular function is of a certain form that makes the calculation of its coefficients straightforward.) Then they showed that any algebraic function can easily be converted to a regular function.

Still another application of this new approach to manipulating power series is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