Communication in physics—the use of journals

Surveys and analysis reveal the interests of readers, authors, publishers and libraries, and indicate that the "electronic journal" may be feasible.

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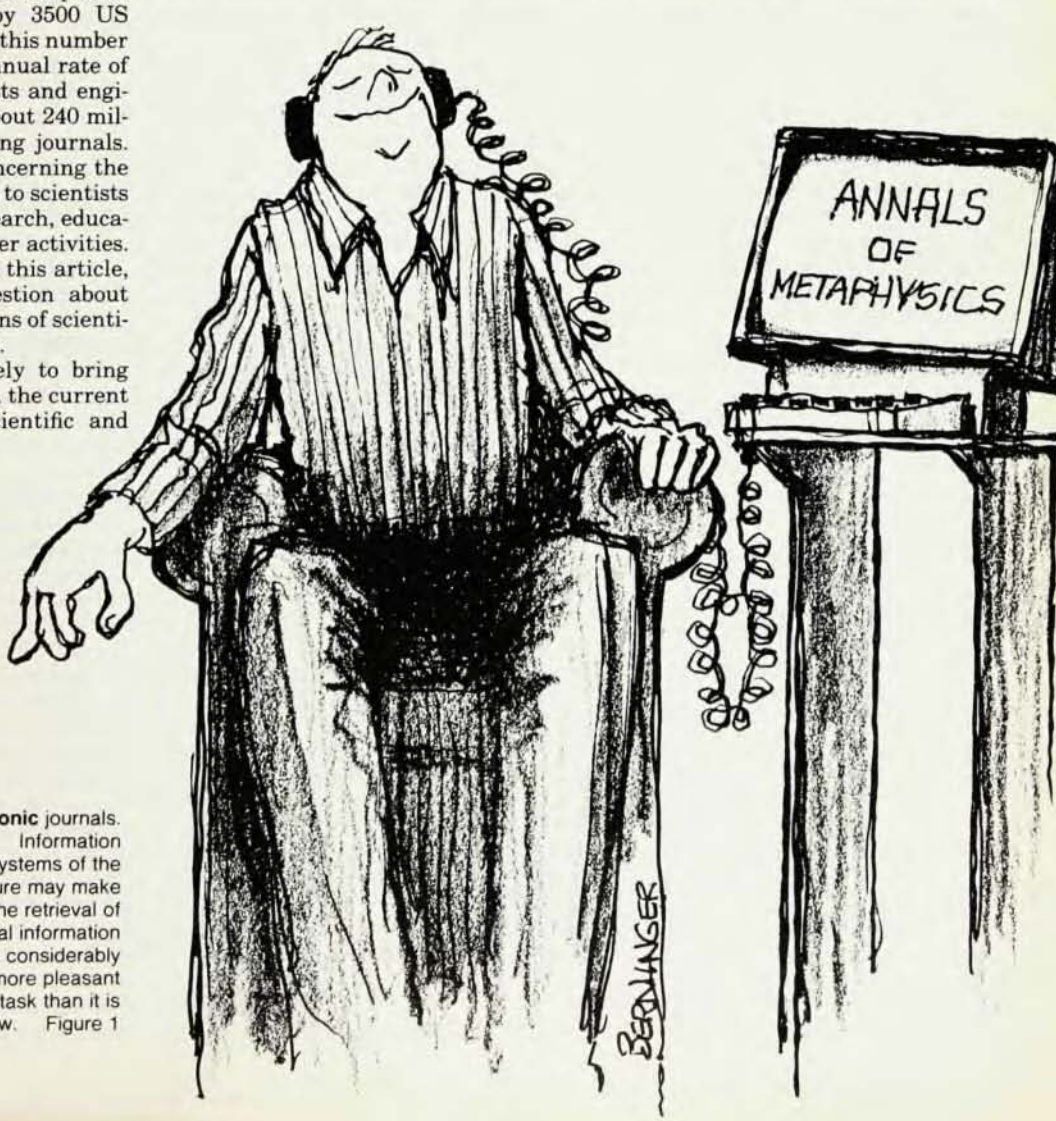
Scientific and technical journals began in Europe in 1665 and were published for the first time in the United States in 1839. Since their inception, these scholarly journals have become the mainstay of scientific and technical communication.

The 7700 scholarly journals published[1] in all fields in the United States include nearly 680 000 articles per year. An astounding 4 billion copies of articles are distributed by 3500 US publishers every year, and this number continues to grow at an annual rate of about 4 percent.[2] Scientists and engineers collectively spend about 240 million hours annually reading journals. There is little question concerning the value of these publications to scientists and engineers in their research, education, management and other activities. However, as we will see in this article, there is considerable question about the future of printed editions of scientific and technical journals.

Several factors are likely to bring about significant change in the current system of distributing scientific and technical information. Economic conditions in the major industrial nations have already caused several perturbations of the traditional journal system. Scientists and engineers are beginning to rely less on personal subscriptions and more on library copies or "separates"—individual copies of articles, such as preprints, reprints or photocopies—obtained from authors and colleagues. Libraries are reducing costs by canceling multiple subscriptions and by relying on interlibrary borrowing. Some libraries have begun to charge for interlibrary loans and other services, such as on-line bibliographic searches. Publishers have also taken steps to reduce costs and increase revenue. They have increased prices and advertising and have begun selling sep-



Electronic journals. Information systems of the future may make the retrieval of archival information a considerably more pleasant task than it is now. Figure 1

arates. Many scientific societies attempt to recover prerun costs (for work such as editing and composition, which must be done before a single copy is reproduced) through page charges and reprint fees.

New technology is appearing throughout the journal system in the form of electronic word processing, computer teleconferencing, computerized editing, electronic composition and on-line bibliographic and numeric data searching. Several organizations are seriously considering distributing separates electronically, either from a central source or by adding a component to bibliographic searches.

In this article we look at journal publishing in physics and attempt to assess the consequences of changing technology and economic conditions. We look first at the current situation of communication in physics.

Reader preferences

There are currently about 450 physics journals, of which 150 are published in the United States. About 23% of the US physics journals are published by scientific societies, 57% percent are published by commercial publishers and 20% are published by other organizations, such as educational institutions, government agencies and companies.

When asked in a 1979 survey[3] to name the five journals they considered to be most important or frequently used, the journals that physicists most frequently mentioned were *Physical Review* (all sections combined), *Physical Review Letters*, *Journal of Chemical Physics*, *Journal of Applied Physics*, PHYSICS TODAY and *Science*. Physicists spend an enormous amount of time reading journals. It is estimated that they spend an average of about nine hours per month reading an average of 16 articles. (By "reading" we mean going beyond the table of contents, title and abstract to the body of the article.) Physicists read the articles for many reasons, including self-education (75%), research (66%), teaching (46%), their own article writing (31%), proposal writing (25%) and management activities (19%).

Physicists are unique among scientists in how they obtain their journal articles. They do a much lower proportion of their reading from personal subscriptions than do other scientists. Over all sciences, about 69 percent of the readings are from personal subscriptions, whereas in physics this proportion is only about 42 percent. One reason for this is that the average nonmember price to individuals for scientific society and commercial physics journals—$97 in 1978—is considerably higher than for other fields of science—$36. (These are averages over titles, and are not weighted by the number of subscriptions.) It is interesting to note that physicists and other scientists spend about the same amount on journals—an annual average of about $360 per person.

The principal reason that physics journal prices are higher is that with an average of 1570 pages published annually, they are almost twice as large as other science journals. The average prerun cost of a physics journal, then, is about $210 000 compared to $100 000 for journals in other fields of science. Also, the price per page purchased is greater for physics journals (8.3¢) than it is for journals of other fields of science (5.8¢). Physics journals have more complex type fonts and graphics, which are very expensive. We should note that while AIP archival journals average about 8.5¢ per page distributed to nonmember subscribers, the price to member subscribers is less than 1¢ per page distributed.

Physicists average about 3.6 personal subscriptions, compared to about 10 for other scientists. Many factors[3] enter into a physicist's decision to subscribe to a journal: Is it a society journal? Is it available in the library (and is the library convenient)? Is it expensive? Two studies performed in the late 1970s give some insight into a physicist's decision to subscribe to a physics journal. In one survey (see table 1), a sample of subscribers to the *Astrophysical Journal* were asked to indicate journal attributes that were important to their work or research. The attributes indicated to be most important were those related to article contents.

An Institute of Physics worldwide survey[5] in 1976 asked physicists about the importance of journal features other than content. In order of importance, physicists cited diagram presentation, price, layout, typestyle, number of pages per issue and size of the pages.

Table 1. Importance of journal attributes

Factor	Rank	Importance (% responding) Low	Neither high nor low	High
Papers are interesting	1	0	10	90
Publication relevant to work	2	1	13	86
Papers by people whose work is relevant	3	1	15	84
Refereeing is competent and fair	4	1	26	73
Publishes unfamiliar work	5	3	32	65
Work not obsolete	6	6	51	43
Quality of printed appearance	7	6	64	30
Price is low	8	14	60	26
Presentation of data	9	16	64	20
Emphasis on theory	10	20	63	17
Length of papers	11	28	63	9
Emphasis on methodology	12	27	64	9
High acceptance rate	13	42	52	6

Survey sample was drawn from subscribers to the *Astrophysical Journal*. From reference 4.

Primacy of price

Price is an important factor in determining whether physicists subscribe to journals or whether they rely on sources such as a library or colleague to get articles. When the effect of inflation is taken out, member prices of American Institute of Physics archival journals have remained relatively constant since 1970, with some minor increases and decreases. In constant dollars, the greatest price increase from 1970 to 1981 was that of *The Journal of Chemical Physics* (+19%) and the greatest decreases (−14%) were with *Journal of Mathematical Physics* and *The Physics of Fluids*. During the same period, the prices of scientific journals in general decreased an estimated 12% in constant dollars. Constant-dollar prices of all chemistry and physics journals, however, increased 118% from 1970 to 1981, as figure 2 shows.

Currently, physicists use library copies of journals for nearly half of their article readings. But libraries, too, are experiencing a severe economic squeeze. Some evidence of this comes from the Association of Research Libraries. In 1972 dollars, the average research library's expenditure on serials went from $389 000 in 1975–76 to $499 000 in 1978–79, and has not increased much since. Thus it is no surprise that the 1976 Institute of Physics survey showed that 63 percent of the libraries considered price *very* important in selecting journals. Price was by far the most important of 13 factors mentioned, including the publisher's reputation and the quality of production. In evaluating brand-new journals, 58% of the libraries cited the state of their subscription budget for the year as a very important factor.

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With the new journals, however, recommendation by the research staff was the highest-ranked factor.

In considering the cancellation of subscriptions, price was not as important as views of the research staff, availability at another library and the number of times the journal is borrowed.

While physicists use libraries more frequently than do other scientists and engineers, they do not do so because they read older articles, which would more often require the use of a library copy. Our surveys show that about 65% of the articles read by scientists and engineers are less than 1 year old, and about 85% are less than 3 years old. The statistics for physicists alone are about the same.

The age of an article read does have a bearing on the source of the article. Physics journal readers use their personal subscriptions for reading current journal articles, and the library and separates for less-current articles.

Page charges

Because price is so important to physicists and libraries that support physicists, a number of scientific societies have instituted a policy of page charges to keep prices to subscribers down. Although these charges affect an author's decision as to where to publish, a number of other factors enter into that decision. The Institute of Physics study of authors of physics articles worldwide determined the relative importance of various factors. As table 2 shows, authors give highest rank to circulation and speed of publication. While physicists worldwide rank page charges 7th, US physicists[4] rank the charges 13th, the lowest rank. Non-US authors may assign higher importance to page charges because they are not accustomed to paying for publication.

Page charges could affect the publication of manuscripts in two ways. Authors might decide to publish their manuscripts in a less expensive journal or they might reduce the number of pages they publish in the journal. There has, in fact, been a slight trend toward a reduction in the number of pages per article—from about 9.2 in 1960 to 8.7 in 1978. The Institute of Physics found that 28% of British physicists would prefer to publish elsewhere if asked to pay page charges, and that a further 43% would "sometimes" seek alternative journals.

Another factor in the relative importance of page charges is who actually pays the charges. Table 3 summarizes our findings. The fact that physics authors rarely pay the page charges themselves makes their choice of a journal less sensitive to the amount levied. Thus the other attributes of the journals are more important, as we saw in table 2. When astrophysicists were asked[4] to indicate the most they would be willing to pay *out of their own pocket* for page charges, their average response was $52.

Publication delay, which averages 5.8 months, is an important concern of authors. In a 1974 survey,[6] Lois Green and Susan Hill found that three out of four physical-sciences authors were moderately to very strongly concerned about such delays. For physical-sciences journals at the time of the survey, the average publication lag was an estimated 8.7 months—3.1 months to accept, 5.6 months to publish. Authors indicated they would be willing to pay an average of $400 more in page charges to cut the publication time in half.

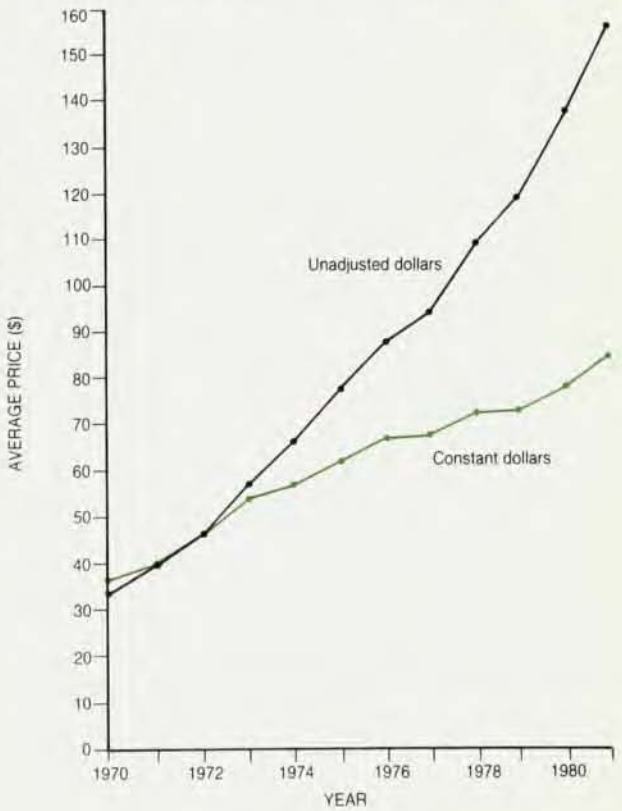
Our research shows that physicists take an average of 72 hours to prepare an article, that 10% of their articles are rejected and that their articles go through an average of 0.6 revision cycles before being published. The data for all scientists are: 82 hours preparation time (see figure 3), 44% rejection rate and 0.9 revision cycles. Our survey data suggest that AIP journals, with a 14% rejection rate, might be slightly more rigorous than other physics journals in their rejection criteria, but the average number of revision cycles is lower (0.2).

It appears that physics authors are also willing to pay something for improvements in features of graphic quality. In the Green and Hill survey, one-half of the responding physics authors indicated they would pay at least:

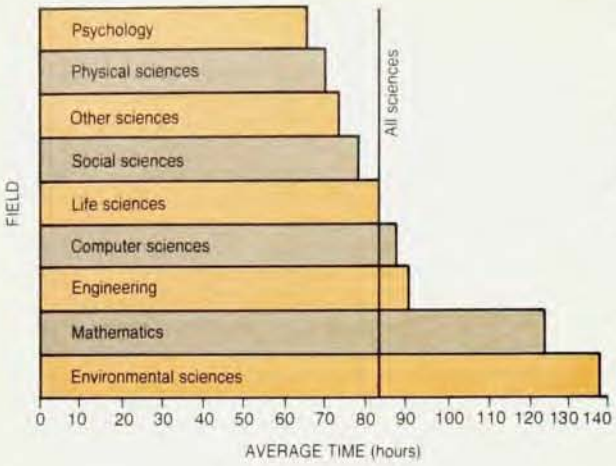
- $5 more to have pages printed with three columns instead of one
- $10 more for pages having six different type fonts and sizes as opposed to three (no increase in value was perceived by increasing to eight type fonts and sizes)
- $5 more for justified margins than for unjustified margins
- $10 more for low-density pages
- $5 more for large printed pages ($6^7/_8'' \times 10''$ or $7^3/_4'' \times 10^1/_2''$) versus smaller pages
- $5 more to have references that give names (Green and Hill, 1975) rather than numbers.[6]

The era of separates

Separates are an increasingly important means of distributing physics articles. Physicists employ several forms of separates, including reprints, photocopies from interlibrary loans, and other photocopies. Data from one of our surveys indicate that for AIP archival journals there are an average of about 2000 readings per article from reprints, 4500 from preprints, 13 500 from photocopies, but almost none from microfilm readers or microfilm printouts. Other physics journals appear to have about the same ratio of readings from these sources of separates; this gives a total of over one million readings per year from separates. We estimate[2] that in all of the physical sciences there are 650 000 readings from reprints and



Prices of chemistry and physics journals are going up rapidly. Average prices for 1-year subscriptions are shown here in unadjusted dollars and constant (1972) dollars. Prices are based on library or institutional rates when these differ from individual rates. (From reference 8.) Figure 2



Time spent by authors preparing articles varies significantly from one field of science to another. Physicists take an average of 72 hours to prepare an article. (From a 1977 survey, reference 2.) Figure 3

1.2 million readings from photocopies. Physical-sciences authors distribute an average of 51 reprints for each article published.

There are fewer data on the number of articles distributed through interlibrary loans. In a 1976 study, we estimated that scientific serials were photocopied for interlibrary lending at a rate of 14.2 million transactions per year. Scientific materials accounted for 64 percent of the total transactions. In an analysis of the Minnesota library teletype system that locates journals and books throughout the state for interlibrary loan, we found that 71 percent of the physical-sciences interlibrary loans were made from academic libraries, 25 percent from special libraries and 4 percent from public libraries.

The Association of Research Libraries gathers statistics[7] on interlibrary lending and borrowing. Their figures show that from 1973 to 1981 the amount of interlibrary lending by the average research library remained at about 14 000 photocopies per year, while the amount borrowed by research libraries increased 38 percent to 2680 photocopies per year. The lending decreased after the new copyright law was enacted in 1976, but increased again in 1978–79.

According to a 1978 study by Indiana University, libraries report that the availability of material on interlibrary loan does not affect their own decisions about acquisitions. The researchers found that while libraries borrow what they don't have, assuming that nothing is too esoteric to be unavailable on loan, they do not cancel subscriptions just because they are able to borrow.

Articles on demand. What about distributing copies of articles on demand? For a number of reasons, there is a great deal of appeal in doing this. Lending libraries find that the interlibrary lending service is costly; libraries and individuals would like to be able to rely on a single source; the sale of single articles would give publishers a hedge against losing subscriptions to interlibrary loans, and it would put publishers in an excellent position to convert to electronic distribution when technology warrants that mode of operation.

The only drawback to this kind of service is that borrowing libraries would have to pay not only their own costs, but those of the distributor. Although reprints are less costly than photocopies, let us assume here that a publisher's distribution cost is the same as that of a lending library. Then it becomes more economical for a library to subscribe to a journal rather than buy separates after eight readings in the library. If the borrowing library did not have to pay the publisher's distribution costs, the breakdown point would be 15 readings, rather than eight. At the Massachusetts Institute of Technology library, 46 percent of the physics journals are used fewer than eight times, as are 36 percent of the physics journals in the University of Pittsburgh library. If publishers can keep the distribution cost less than the lending library cost, then the overall cost to libraries would be less. We calculate[9] that libraries minimize their overall costs by setting the breakeven point at the total costs incurred by the borrowing and lending libraries, whether or not the lending library actually levies a charge. This is exactly what happens if a publisher or consortium does the on-demand distribution. Across the board, then, providing articles on demand is a more economical system.

Electronic journals?

We have seen two significant developments that may lead to the electronic distribution of physics articles. One is the extensive on-line use of computers to search for and retrieve bibliographic references. The other is the extensive use of electronic word-processing and text-editing systems by authors and publishers.

Word-processing systems involve electronic typewriters with memories. Text-editing systems range from terminals that tie into a local computer to intelligent terminals with self-contained memories and microprocessor-based computing functions. These systems improve the editorial quality of manuscripts and make their preparation and revision faster and much more reliable. Publishers also make extensive use of electronic processing for editing and composition. Submission of electronically encoded text by authors to publishers would add to the advantages of such processing. It would save the publisher the cost of keyboarding. This type of integrated system is often used by newspaper publishers.

In the future, publishers will have enormous flexibility in the form of articles they can make from computer-stored "master images." In fact, electronic technology already makes it feasible to produce individual copies of articles with computer printers. Nonimpact printing has eliminated the problem of slow computer printout. The ink-jet and photoelectrostatic (or laser) systems hold substantial promise for scientific and technical publishing.

Library operations and services are

Table 2. How physics authors select journals

	Rank	Importance (%) High	Marginal	Low
Circulation (size and nature of audience)	1	82	16	2
Speed of publication	2	72	26	2
Publisher's reputation	3	65	26	9
Refereeing arrangements	4	54	38	9
Quality of production	5	43	49	8
Availability within own institution	6	43	43	14
Page charges for authors	7	35	45	20
Frequency of publication	8	32	57	11
Charges for off-prints	9	9	42	49
Price of journal	10	8	42	50
Published by member society	11	4	30	66
Tradition within department	12	3	37	60
Instructed to do so	13	3	20	77

From reference 5

Table 3. Who pays page charges?

Journal	Proportion who pay	Who pays			Average paid per article
		Self	Government	Other	
AIP journals	93%	0%	60%	40%	$550
All physics journals	89%	4%	54%	42%	$370
All science journals	33%	18%	54%	27%	$208

areas in which new technology has been applied directly to scientific and technical communication. The most prominent applications are to cataloging of books, on-line and off-line bibliographic searches, and record keeping for circulation and interlibrary loans. Mass-storage memories and video disks will make these library systems more efficient.

Voice-grade telephone lines have proved adequate for most telecommunication. Thus the existing telephone network is a potentially low-cost system for scientific and technical communication. Its potential is enhanced by the availability of minicomputers and intelligent terminals, whose buffers permit rapid transmittal of messages. Furthermore, new technology in long-line communication, such as fiber optics, communication satellites and digital transmission and switching equipment, can decrease the cost of communication if their capital costs can be shared by enough users.

These advances in technology, although not developed specifically for scientific and technical communication, nonetheless provide all the parts for a comprehensive and flexible electronic alternative to paper-based publishing of scientific journals. Individual articles could be distributed in the most economical manner: Frequently read articles might still be distributed in paper form, while infrequently read articles could be requested and received quickly by telecommunication when they are needed. Resources that were formerly wasted in printing, mailing and storage could be applied to better identification and retrieval of information. Better integration of systems will result in a greater emphasis on the quality of an article's content; fewer articles will be repeated over and over again for updates or for different journals; and users will have better access to information needed in multidisciplinary research.

Practical problems. Technological constraints do exist. Standards must be set so that publishers can receive word-processing and text-editing output and easily convert it to the appropriate format. A major problem is the treatment of nontextual input such as tables, graphs, photographs and mathematical and chemical formulae. Although we can now handle graphics electronically, it is not yet economically practical to do so with physical-science articles because of their abundance of graphics.

Authors, publishers, libraries and journal users also put some major constraints on the adoption and use of an electronic journal system. One problem is the lack of incentive for these participants to change.[10] Authors, for example, are said to publish in part for prestige and recognition that results in professional advancement. Certainly, any alternative communication system must meet the perceived needs of those who work in the "publish or perish" environment that exists in some fields of science and in some organizations.

Also, many publishers have no financial incentive to deviate drastically from current journal publishing practices. While many publishers of books and small journals appear to have financial problems, most large publishers are making comfortable profits. Journal publishers require much less capital than book publishers because the income from journal subscriptions is received before most costs are incurred. Therefore, the return on investment in journal publishing is higher. Substituting photocopy royalty payments for subscriptions lessens this advantage somewhat; because photocopying takes place on many older publications, the publisher's royalty income is spread out over time. Another problem is that publishers derive some income through the sale of advertisements, which the distribution of separates appears to obviate. Thus, any new publishing systems must incorporate some financial incentives, otherwise publishers are unlikely to want to change.

Scientists as users also present some barriers to new systems when those systems affect their behavior directly. It has been claimed for many years that scientists would adapt quickly to the direct use of computer terminals and would search bibliographic data bases on-line. However, while some scientists do this, most still rely on an intermediary to perform their searches for them. This is the case in part because many scientists are without easy access to terminals, and in part because some are reluctant to use terminals. Whatever the reasons, scientists will need some incentives to alter their behavior before they will use an alternative journal publishing and distribution system involving direct on-line communication. Perhaps, in the future, new scientists who have been trained on terminals in high schools and universities will find it unacceptable not to have these facilities available for analysis, text processing, search and retrieval and other forms of communication.

Libraries will have little incentive to change their mode of operating unless their patrons and funders find change desirable. While many libraries currently are becoming automated for cataloging and internal record keeping, they still require motivation to change their procedures in dealing with scientists. Thus, if we are to modernize scientific communication, each component—scientists, publishers and libraries—will need some outside incentive to change.

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