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Whither Libraries? or, Wither Libraries

The claim is made that society is evolving from one whose formal communication patterns have, for centuries, been based primarily on print on paper to one in which communication channels will be largely paperless (electronic). Some reasons why this transition seems inevitable are discussed. A scenario for a paperless communication system is presented, and some technological achievements that lend credibility to this scenario are described. The profession is urged to give immediate and serious consideration to the role of the library in an electronic society.

THE PROBLEMS CONFRONTING libraries, particularly research libraries, have received much attention in the last few years. It has frequently been said that libraries face a "crisis." The causes of this crisis are already identified. A typical academic library, while doubling its expenditures in less than a decade, finds itself with a budget that buys proportionately less and less of the newly published literature, because the cost of this literature and of personnel to handle it are both increasing much faster than general indicators of inflation in the economy. At the same time the literature continues its inexorable growth, and many libraries, despite being unable to "keep up" with this growth, face acute shortage of space.

These problems have been addressed by many writers, some of whom have suggested what the library needs to do, now or in the future, in order to cope with them. The implications of escalating costs of periodical subscriptions, for example, are dealt with by Fry and White[1] and, less thoroughly but more entertainingly, by De Gennaro.[2] The space problems are discussed by Gore,[3] and Baumol and Marcus have provided a rather comprehensive analysis of the economics of academic libraries, highlighting the labor-intensive nature of library activities.[4]

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Proffered solutions to these problems include increased sharing of resources through networking and other cooperative activities, deliberate curtailment of library growth (the "zero growth" library), more "scientific" approaches to the selection and retirement of materials, and increased reliance on library automation.

All these solutions assume that publications, the raw materials with which libraries deal, will continue to exist in much the same form in which they have appeared for the last five hundred years, i.e., as print on paper or as micrographic images of print on paper. Library automation is seen only as the application of computers to the manipulation of machine-readable records for documents in print on paper form. In the librarian's view (see, for example, Josey[5]), the library of the future looks only cosmetically different from the library of the present.

Salton, one of the most outspoken critics of library operations and approaches to their automation, seeks a solution in the form of a "self-reorganizing" library but is still preoccupied with the handling of documents in print on paper form; only their representations are manipulated by computer.[6] Licklider is one of the very few writers to come close to a realistic vision of what the library of the future may really look like.[7] But Licklider has not been taken too seriously by the library profession.

It is my belief that the prevalent view in the profession of the library of the future, and how this library will handle the problems already besetting it, is myopic in the extreme. This view ignores the significance of many social, technological, and economic trends, quite evident in the world around us, that point unambiguously to the fact that many types of publication, perhaps the great majority, are highly unlikely to exist indefinitely in print on paper form. The National Science Foundation has stated the case rather clearly:

> The limits of what can be communicated by printing, mailing, storing, and retrieving pieces of paper may be at hand. Certainly, for any real improvement in the accessibility and usefulness of information an alternative must be found.[8]

Whether we like it or not, society is evolving from one whose formal communication has, for centuries, been based almost exclusively on print on paper to one whose formal communication will be largely paperless (i.e., electronic). Why this evolution, which is a completely natural process, appears inevitable, and what an electronic communication system may look like, will be discussed in the remainder of this paper.

Paperless Systems

Publications exist, presumably, as a means of transmitting messages from one individual (writer), or a few individuals, to a great many other individuals (readers). The message may consist of results or opinions based on scientific or humanistic research, industrial or commercial experience, or some other facet of professional practice. Such messages are disseminated for their potential value as sources of information. Other types of messages, such as poetry and novels, are presumably disseminated for their potential value as sources of entertainment or inspiration.

They are disseminated as documents in the form of print on paper because, for many types of message at least, there has been no other convenient way of reaching a wide audience. This situation is now changing. It is now possible to transmit messages in a completely electronic mode. The message is keyed at some on-line computer terminal and transmitted, probably by regular telephone lines, to many other terminals at which it can be read. The message can be stored "electronically" by the recipient, who can also do many other things to it (e.g., index it, add to it, annotate it, redistribute it) without in any way generating paper copy.

In an electronic environment of this kind, paper does not need to exist at all. It seems highly probable that, in the future, the great majority of "messages" now created and distributed as print on paper will no longer be created and distributed in this form. Instead, they will be distributed electronically. This is likely to apply to all types of message now transmitted for their information content (but not necessarily those designed for entertainment), including indexing and abstracting services (which will undoubtedly be the first to disappear in printed form), handbooks, directories, technical reports, patents, standards, the science journal, and journals in the social sciences and the humanities.

The implications of this for libraries are obviously of the greatest significance. The library problem will no longer be one of inadequate space. It may not even be one of inadequate financial resources. Rather, it is likely to be one of justification for existence and simple survival. Will libraries be needed in an electronic world in which documents exist in machine-readable rather than printed form and any such document can be accessed by any individual who can reach a terminal wherever that document happens to be stored?

Before a document can be disseminated electronically, two requirements must be satisfied: (1) It must exist in a machine-readable form, and (2) the audience to whom it is directed must all have receiving terminals readily accessible to them. Clearly, these requirements are not satisfied at the present time, although it is very likely that they will be satisfied, for a wide range of documents and users, in the future. Moreover, the requirements are now beginning to be satisfied in some rather specialized applications. The most notable example is the defense/intelligence community. A large part of the documentation of intelligence interest—perhaps in excess of 60 percent—is already transmitted "electrically" through wire communications devices.

If the majority of the intended recipients have on-line terminals readily accessible to them, there is no need to generate paper copy at the point at which the message is received. Instead, the message can be disseminated to a user terminal, read there, put into an electronic file, redirected, or disposed of in some other way. In point of fact, the intelligence community in the United States is moving rapidly towards such paperless systems. Many components already exist. So do prototype systems in which documents are generated, transmitted, used, stored, indexed, and retransmitted in a completely paperless mode.

The intelligence community is in an unusually fortunate position in terms of the implementation of electronic systems of this kind. In addition, its need for such systems exceeds, perhaps, that of any other community: the volume of documents disseminated is extremely large (several thousand each day), and these must be distributed and acted upon very rapidly. But there is no reason to suppose that paperless systems will be restricted to defense/intelligence applications. Indeed, it seems almost certain that they will emerge in virtually all fields of human endeavor.

Take, as an example, the publication system by which the results of scientific research and technological experience are formally transmitted. The health of this science communication system is of great importance to all of us. Economic, social, and industrial progress are all dependent on scientific discovery and technological invention. These, in turn, depend heavily on the ability of the science community to assimilate the results of previous research, since modern science is a social activity in which progress is made through group endeavor and a process of gradual accretion, one group building on the work of another.

But the results and interpretation of completed research can only be assimilated by the science community if they are properly reported and the reports efficiently disseminated throughout the community. Authors, publishers, librarians, information scientists, indexers, abstractors, and many other individuals all play very important roles in this communication cycle. A breakdown in the cycle could have very serious consequences. Science itself would stagnate if its own achievements were no longer reported, disseminated, and assimilated in an efficient manner.

I believe that the formal science communication system, still heavily dependent on a science journal that has changed relatively little in 300 years, is already showing signs of breaking down. Some channels are almost closed. Others are beginning to close. As long as we continue to disseminate the results of science research as print on paper, the situation will inevitably deteriorate further. These results are becoming increasingly less accessible to that part of the population that relies on the printed word. There is no long-term solution to this problem through publication and distribution of information in print on paper form.

Present Problems in Science Communication

Why do I feel it necessary to paint such a gloomy picture? There are now many problems involved in the use of the literature of science and technology, especially in the "current awareness" aspect of its use. One obvious problem is simply that of growth. As the field of science and technology itself grows, there are more research results and practical experiences to be reported. The literature grows, then, in step with scientific and technical growth and at a very rapid pace.

This "information explosion" really has two dimensions. This can be seen if we consider the distribution of documents as essentially a packaging problem. The dimensions of growth then become: (1) growth in the number of packages and (2) growth in the size of the packages.

Growth in the number of packages is well exemplified by the growth in the number of published journals in science and technology. Best available estimates indicate that there are now about 50,000 journals in scientific and technical areas published throughout the world and that this number is steadily increasing at a compound rate in the range of 2 to 4 percent a year (the rate of growth has not been established precisely to everyone's satisfaction).

If this were the only dimension of growth, the problems created would be less serious than they actually are. But the size of the packages, as well as their number, is increasing. That is, each journal tends to increase in size as more papers are written and submitted for publication. For example, Sandoval et al. have reported that *Biochimica et Biophysica Acta* has been growing at an approximately logarithmic rate since its foundation in 1947. This journal now doubles in size about every 4.6 years.[9]

Besides growth in number and size of journals, of course, we have growth in numbers of technical reports, patents, dissertations, films, videotapes, and other documentary forms. This growth in the volume of literature published creates great problems for anyone who wants to keep up to date in any field of specialization. The problem is simply this: The literature of the field grows rapidly, but the time that any individual has to read it remains more or less the same. A hypothetical scientist spends 10 percent of the working day in "keeping up with the literature," and this proportion is the same in 1976 as it was in 1966. Yet, twice as much is published in 1976 as was published in 1966. Thus the scientist must either fall further and further behind in current awareness activities or must improve efficiency by using better methods of surveying the literature.

Since secondary publications are guides to and synopses of the primary literature, it is obvious that these too must increase at approximately the same rate as the primary literature. Once more, we have increases in the number of secondary publications as well as increases in the size of these publications. It has been estimated by Ashworth that there are about 3,500 such publications in existence in the world and that about 1,500 of these are in scientific and technical fields.[10] The "internal growth" of secondary publications was demonstrated by Ashworth in the following remarkable data on the number of years it took *Chemical Abstracts* to publish successive millions of abstracts:

First million	32 years (1907–38)
Second million	18 years
Third million	8 years
Fourth million	4.75 years
Fifth million	3.3 years

Clearly, if the primary literature of chemistry continues its pattern of exponential growth and if *Chemical Abstracts* continues to attempt to keep up with this growth, we are rapidly approaching a time at which *Chemical Abstracts* must publish a million abstracts in a single year.

A problem closely related to the growth of the literature is the *dispersion* or *scatter* of the literature. The more a particular subfield of science grows the more dispersed the literature is likely to be. In a typical field of research, all the papers published are likely to be scattered among a great number of journals, although quite a high proportion may actually appear in a relatively small number of "key" journals in the field.

To take a hypothetical case, there may be 375 papers published in a particular subject area in a single year. These are widely scattered over 155 journals. A small number of journals, only five in fact, contribute about a third of all the papers, and as few as thirty journals may contribute two-thirds of all the papers, but the final third is distributed over as many as 125 journals.

A hypothetical scientist who routinely scans five journals in his or her field of specialization, if lucky enough to choose the most productive five, might cover as much as one-third of the published papers. The scientist would need to routinely scan very many more journals—about thirty in this example—to increase coverage to two-thirds of the published literature and could do this only if fortunate enough to scan the most productive thirty journals. Very few scientists scan this many journals. In fact, a typical scientist is likely to scan only five or six regularly.

The only way to keep up to date effectively, then, is by scanning secondary publications or, better yet, participating in a current awareness service in which a computer is used to search this secondary literature. It is no longer possible to keep well informed simply by scanning a small sample of the primary literature. Even through the use of secondary services scientists are unlikely to discover every paper of potential relevance to their interests, but they might be able to push their coverage up to, say, 90 percent, which is a great improvement on what one could expect to achieve by scanning only the primary literature.

Another problem is that there are quite substantial delays involved in the publication of primary and secondary literature. There may be a delay of several months, and perhaps more than a year, from the time a paper is submitted for publication to the time it actually appears in print. There will also be some delay from the time a research project is completed to the time a paper describing the project is submitted for publication. Thus the paper published in the science journal is likely to report research completed many months earlier.

As more papers are written and submitted for publication, publication "backlogs" develop and greater delays occur because many papers are competing for the limited publication space available. Roistacher, for example, quotes the case of the journal *Sociometry*, which in 1974 received 550 manuscripts for review but had space to publish only 39 of them.[11] As publishing space becomes increasingly scarce, because publishers restrict growth in an effort to contain price increases, publication delays increase.

It is a delusion to regard the science journal as a reflection of current science research. Indeed, it is more archival than current, reporting research concluded many months ago and perhaps begun years earlier. Information from this research has long ago been disseminated to those well integrated socially within the science community. Professionals who want to keep at the forefront of their fields cannot rely on the science journal alone but must also use other types of documents (e.g., technical reports) and, more importantly, turn to informal channels of communication.

The final problem that should be mentioned is that of cost. The publication process is a very expensive one, and publication costs have been increasing extremely rapidly because of increasing costs of labor, materials, and physical plant. The cost of publications to the buyer must also increase to keep pace with these inflationary elements in production. The problem is particularly severe in that not only are production costs increasing but the amount to be published is also increasing. Publication costs would increase even if the amount published remained the same. But when the amount published and production costs both increase, the resulting price increases to the buyer become very serious.

The most severe price increases have affected the secondary publications. Some of these have experienced price increases of 850 percent in a ten-year period. In 1940 *Chemical Abstracts* could be purchased for only $12 a year. In 1976 it cost $3,500 to subscribe to this publication! The primary literature of science has also experienced great price increases. The average subscription price for a chemistry or physics journal in the United States, for example, went up from $18.42 in 1965 to $65.57 in 1975, and further substantial increases are forecast. De Gennaro mentions the case of *Inorganica Chimica Acta*, which was available to libraries at an annual subscription of $26 in 1970 but cost $235 in 1975, a staggering increase of 804 percent.[12]

The implications of these price increases are obvious. The cost of some science publications increased several hundred percent in a period in which the rate of inflation in the economy (as measured, for example, by the Wholesale Price Index) was only 60 percent. *Psychological Abstracts*, to take but one example, increased in price from $20 in 1963 to $190 in 1973. The accessibility of this publication is thus greatly reduced unless the average salary of a psychologist increased by a comparable 850 percent in the same period, which is clearly not the case. The trend is unambiguous. The secondary publications of science have, to a very large extent, priced themselves beyond the pocket of the individual scientist. They have become available only in libraries.

But the greatly increasing costs of at least some of these services are putting them beyond the reach of the smaller institutions. Thus they become available only in the larger, wealthier institutions. The same fate is in store for the science journal. The ratio of institutional to individual subscribers is changing, slowly but surely, in favor of the former. Baumol and Ordover point out that "a growing proportion of scientific journals have virtually no individual subscribers but are sold almost exclusively to libraries,"[13] and De Gennaro claims that "many commercial publishers have lost interest in personal subscribers and no longer quote rates for them in their advertising copy."[14]

The primary literature of science will soon be accessible only in libraries; later, the more expensive journals will be accessible only in the larger libraries. If scientific publication continues in its present form, it seems inevitable that primary journal subscriptions will continue to move to the institutional subscriber, while the major secondary services will move increasingly out of the reach of the smaller or less wealthy libraries. The general accessibility of the literature declines as a result.

The fact that the cost of science publications is increasing at a much faster rate than general indicators of inflation in the economy is very largely due to the fact that the printing and publishing industry is still very labor-intensive and, unlike many other industries, has not been able to increase its productivity substantially through automation. The industry lags far behind most others in this respect. This is evident from an examination of the Industrial Production Index. Between 1967 and 1974, U.S. industry as a whole increased its productivity by some 24.8 percent. The rubber and plastics industry increased its productivity by 64.4 percent. But productivity in the printing and publishing industry grew only 12.3 percent in this same period.

Libraries, as suggested earlier, find themselves in an unusually adverse situation in this economic picture. Libraries constitute a labor-intensive industry that is dependent for its raw materials on another labor-intensive industry. This causes the problems identified earlier: budgets growing rapidly but dwindling in purchasing power relative to total expenditures. Thus figures prepared by Dunn et al. indicate that the mean expenditures of fifty-eight major research libraries increased 103 percent between 1965 and 1972.[15] In this same period, mean expenditures for materials and binding increased only 78 percent, and these libraries were adding only 35 percent more volumes in 1972 than they were in 1965. As Baumol and Marcus have shown, the cost of operating libraries increases rapidly even in a period of comparative stability in the economy as a whole.[16]

The only long-term solution to all these problems appears to lie in a greatly increased level of automation in the complete system through which the results of research (in science, the social sciences, technology, the humanities) are disseminated, stored, retrieved, and used. In other words, the only solution, in these fields as in the intelligence field, lies in completely paperless (i.e., electronic) information systems.

THE ACHIEVEMENTS OF AUTOMATION

Considerable improvements in access to sources of scientific, technical, and other information have already occurred through automation. The two major developments have been the rather phenomenal growth of machine-readable data bases and the equally impressive spread of on-line systems to make these accessible. It is reasonable to accept the MEDLARS data base of the National Library of Medicine, dating from 1964, as the first such data base to be widely used in the provision of information services. It is now estimated that there are in excess of 500 data bases or data banks used routinely in the provision of various types of information service, and more and more of these are becoming readily accessible on-line.

MEDLARS provides a good illustration of the increasing accessibility of information sources through automation. In 1965, when the MEDLARS retrospective search service was just beginning, virtually all of the expertise in searching this data base was concentrated in a handful of search analysts on the staff of NLM itself, and the volume of searches that could be conducted in the United States was severely limited, perhaps to something on the order of 3,000 a year.

When the MEDLARS off-line network was fully developed at the end of the decade, the situation had considerably improved. Through the establishment of a network of regional MEDLARS centers and through the training of information specialists on the staffs of these centers, the number of qualified MEDLARS analysts increased considerably, to perhaps fifty active searchers, and the number of searches handled in the United States rose to about 20,000 a year.

The move to on-line processing, in the 1970s, caused a further dramatic improvement in the situation. In 1975 there were about 300 MEDLINE centers operating in the United States, the number of trained searchers had increased to perhaps 500, and the number of searches conducted had grown to about 20,000 each month in the United States alone, with many additional searches occurring elsewhere in the world.

The cost of access to information sources on-line has also declined dramatically. In 1970, when I began to demonstrate on-line search capability at the University of Illinois, the cost of a one-hour demonstration was estimated to be about $50, of which about $3 was actual computer time and the remainder was communications costs (a regular telephone call to California). Now, through TELENET, the data communication network operated by the Telenet Communications Corporation, the same demonstration can be conducted at a total communication cost of $3.

In 1977 Bibliographic Retrieval Services was quoting on-line connect costs as low as $10 per hour for high-volume users (about eighty hours per month). For use of data bases for which no royalties are charged, these rates bring the cost of an average on-line search down to something in the neighborhood of $2.50 to $3.50, exclusive of terminal rental or purchase costs (minimal when amortized over many searches), the time of the searcher, and cost of printing citations off-line. Even with a royalty charge of $15 per connect hour, the total on-line costs for a search could be as low as $5.75 to $8.50.

On-line access to many data bases is already cheaper than the purchase of printed access. It costs $3,500 a year in subscription alone, ignoring storage and handling costs, to make *Chemical Abstracts* accessible on library shelves. But an on-line search of this data base might be conducted, through Bibliographic Retrieval Services, for $10 or less and is likely to be much more effective than a search of the printed tool. A library would need to do 350 searches a year in *Chemical Abstracts* to bring the per-search cost of data base access in printed form down to the per-search cost of access on-line.

Machine-readable data bases and on-line technology change the entire economics of access to information sources. Purchase of access to a data base in printed form requires a capital outlay in subscription, in storage, and in handling costs. This investment can only be justified if the annual volume of use of the data base is sufficient to bring the cost per use down to a reasonable level. But on-line services make data bases accessible in an on-demand, "pay as you go" mode, and their costs are much less dependent on volume of use. In fact, they make data bases readily accessible to libraries that could not afford to purchase access to the printed equivalents.

In summary, the growth of machine-readable data bases, and of on-line access to these, has had the effect of: improving the availability of information sources, drastically reducing geographic distance as a barrier to communication, making information sources as readily accessible in a small community as they are in a major city, and significantly reducing the cost of access to these resources.

It would be true to say, in fact, that the electronic accessibility of information resources is improving as rapidly as the accessibility of printed sources is declining and that the cost of electronic access is falling as rapidly as the cost of printed access is climbing. Moreover, and this is the most important point, cost and accessibility though electronics will continue to improve, while cost and accessibility through print on paper can only get worse and worse.

A Scenario for the Future

Significant achievements in automation have occurred, then, in the publication of secondary services, in the resulting growth of machine-readable data bases, and in the rapid increase in information services derived from these data bases. Other achievements, although less impressive, have occurred in the automation of acquisitions, cataloging, circulation, and other library activities.

Automation has so far had much less impact on primary publication and almost no impact on the distribution and use of primary literature. Yet, major improvements in the dissemination and exploitation of information will only come when the entire communication cycle—from the composition of a document to its distribution and use—is automated. In other words, these major improvements depend on the emergence of completely paperless information systems. I believe that such systems will emerge; indeed, they are inevitable. What, then, is a science communication system likely to look like in, say, the year 2000?

There are, of course, some basic assumptions underlying any discussion of a paperless future. These assumptions are that computers will continue to increase in power and decline in cost, that methods of data transmission will become more efficient and less costly, that new storage devices will make it economically feasible to hold extremely large volumes of text in a readily accessible form, and, most important of all, that computer terminals will be reduced in price to a point at which every scientist will have such a device in the office and, very likely, in the home. All of these developments, which seem highly probable, will produce the communication "structure" that will permit the substitution of the electronic medium for many of the activities and institutions that we now take for granted as operating largely on the basis of print on paper.

The scientist of the future will use a terminal in many different ways: to receive text, to transmit text, to compose text, to search for text, to seek the answers to factual questions, to build information files, and to converse with colleagues. The terminal on the desk will provide a single point of entry to a wide range of capabilities that will substitute, wholly or in part, for many activities that are now handled in different ways: the writing of letters, the receipt of mail, the composition and distribution of research reports, the receipt of science journals, the collection of documents into personal files, the searching of library catalogs and printed indexes, the searching of handbooks of scientific data, visits to libraries and other information centers, and even certain types of professional "conversations" now conducted through the telephone or face-to-face encounter. In brief, the scientist (or, indeed, other professional) will use some form of on-line terminal to compose text, transmit text, receive text, conduct searches for data or for text relevant to a particular research problem, and build personal information files.

We can reasonably assume that the scientist will use a terminal as a type of electronic notebook in which details and observations on ongoing research are recorded. These informal notes, recording background to the study, equipment and methodology used, results achieved, and interpretation of these results, can be entered at any time into a designated "ongoing project file." It is from these informal notes that the scientist will construct research reports.

The reports themselves, both those that must be submitted regularly to a sponsoring agency and those to be made more widely known through some more formal publication process, will be written at the terminal. In the process of composition, the author will, of course, draw from the notes in the electronic notebook. Some rather sophisticated text editing programs will make it very simple to make alterations in the text—transposition of sentences or paragraphs, deletions and corrections, and even the wholesale substitution of one word for another throughout the report. In addition, there will be available various on-line reference tools, including dictionaries and data banks of various kinds, which will make the task of accurate reporting so much easier. Presumably, too, the author will have the capability of electronically copying into a report any quotations, tables, or bibliographic references to be drawn from reports already accessible in machine-readable files. In an electronic environment, the problems of checking bibliographic references will be an order of magnitude more simple than is true at present.

When reasonably satisfied with what has been written, a scientist may decide to have the report reviewed, in an informal way, by some professional colleagues. The scientist will submit the draft to these colleagues, within his or her own institution or far beyond it, electronically. This may mean that the text is copied from one's personal files (which no one else may access) into some controlled access file. A message, addressed to those colleagues who are to review the report, is put into the communication system. The message asks these individuals if they would examine the draft and gives the information (including a password) that will allow them to access the text. When one of these scientists next goes into a "mail scan" mode at a terminal (which could conceivably be seconds after the message is entered), that person will see the message and, when ready to do so, call up the text for examination. The comments of the reviewers are transmitted to the author in the same way.

The author, of course, may choose to modify the report on the basis of the comments received. When it reaches its final form, the report may be transmitted electronically to its final destination. This may be the files of a sponsoring agency, or it may be the publisher of some electronic journal.

I suggest that the publication of primary literature in the year 2000 may in fact be a more or less direct electronic analog of the present system. Descriptions of ongoing research projects will get into on-line files similar to those now maintained by the Smithsonian Science Information Exchange. Patents will be stored in machine-readable patent files, dissertations in dissertation files, standards in standards files, and so on. Unrefereed technical reports would be accessible through data bases maintained by government agencies and other sponsors of research.

Science "journals" would continue to be published by professional societies and commercial enterprises. By this I mean that these organizations would build machine-readable data bases, in special subject areas, that would be roughly comparable to the present packaging of articles into printed journals.

Thus I can visualize the existence of an applied physics file, maintained by the American Institute of Physics; a heat transfer file, maintained by the American Society of Mechanical Engineers; and so on. Refereeing would continue, but all communication among referees, authors, and editors would take place electronically. The allocation of reports to referees could be handled more efficiently through on-line directories of referees, through automatic scheduling and follow-up procedures, and perhaps through some profile-matching algorithm, which allocates each report to those available referees whose interests and experience coincide most closely with the scope of a particular article. Acceptance of an article into a public data base implies that the article has satisfied the scientific review process and received the "endorsement" of the publisher.

In the electronic world, however, space considerations are less likely to be a major constraint on how much is accepted for publication. This may mean that more articles can be accepted by the first source to which they are submitted, resulting in greatly reduced delays in making research results widely accessible. It may also mean that acceptance for publication need no longer involve a binary decision. Instead, as Roistacher suggests, the refereeing process may lead to the allocation of some type of numerical score to a paper, the score reflecting the judgment of the referees on the value of the contribution.[17] Every article having a score above some pre-set value would be accepted into the data base, the score being carried along with the article. Even the articles falling below the required value might, with the permission of the authors, be accepted into a second-level data base.

Once the articles become accessible to the scientific community at large, a form of "public refereeing" becomes possible. The system itself can record the degree of use that a particular item receives, readers can assign their own weights to an article, using some standard scale, and they can place their comments (anonymous or signed) into a public comment file, with comments linked to the identifying numbers of articles. The electronic system, then, may allow an author, whose contribution received a low initial rating from the referees, to be "vindicated" by the reaction of the wider community of scientists.

The processes by which an article is submitted, reviewed, and accepted for publication may not, then, be radically different in the year 2000 than they are in 1977. It seems more likely, however, that a paperless system may force rather sweeping changes in the way the science literature is distributed and paid for. It would certainly seem undesirable if the distribution procedures of the electronic system are more or less direct equivalents of the present situation.

If a scientist is expected to subscribe for the privilege of accessing one or two data bases, a major defect of the present system—the rather inefficient way in which reports of science research are packaged—would simply be perpetuated. Obviously preferable would be some immense SDI service through which scientists are automatically notified of any new report, added to any accessible data base, that matches a stored profile of their interests. They could then use a terminal to access the full text of any item brought to their attention by the SDI service that they wish to pursue further.

The implementation of a global SDI service of this kind is technologically feasible right now, but it raises major questions relating to organization, administration, and division of responsibility. How many SDI services should exist in the electronic environment, and who should manage and maintain them? It would certainly seem inefficient if each publisher of primary data bases must maintain its own SDI program. Perhaps this function would become a prime responsibility of the present publishers of secondary services. Thus we might expect to see the emergence of national and international on-line SDI services, based upon discipline-oriented and mission-oriented secondary data bases.

Individual users would be billed for the amount of SDI service they receive, the great size of the population served bringing the cost per individual down to a figure that could become rather insignificant. The SDI services used would bring the scientists citations, and perhaps abstracts, of new literature (from all types of sources) matching their interest profiles. For each item brought to their attention in this way, the system will be able to provide, on request, an indication of how they can access the full text and how much it will cost to access it. A scientist who chooses to access the complete text of any item, which would be maintained in the files of a primary publisher, must presumably pay for the privilege of doing so. The paperless communication system is likely to be much more a "pay as you go" one, with individuals paying for just as much as they choose to use rather than subscribing to conventional journal packages, a large part of the contents of which may not be directly relevant to their interests.

The secondary publisher would presumably continue to be involved in the indexing and abstracting of the primary literature, although most of the abstracts would simply be those provided by authors and primary publishers. All indexing, of course, will be carried out on-line.

The "scope" of a secondary data base, however, would no longer be defined in terms of a list of journals (or other sources) covered. Instead, I foresee the need for various levels of SDI within the communication system. The interest profiles (gigantic ones) of the secondary publishers would be matched against updates of primary data bases so that items of potential interest would be disseminated to these secondary services rapidly and automatically.

The customers of the secondary publishers, and/or of information centers, would in turn have their interest profiles matched regularly against the data bases of these institutions. This, of course, is just one possible "model" for a dissemination system of the future. The model may seem a rather radical departure from the ways in which primary publishers, secondary publishers, and information centers now operate. But, if we are indeed moving into an electronic age, such radical departures from tradition are almost inevitable.

Scientists, then, can have their interest profiles matched regularly against one or more SDI services operated by secondary publishers or by some form of information center. These services, to which they or their institutions subscribe, will draw their attention continuously to new literature of all types—research reports, journal articles, dissertations, patents, standards, regulations—corresponding to their current professional interests. I use the term "continuously" deliberately, because I view this as an operation in which the scientist can reasonably expect to get a few things each day in the mail, rather than receiving a much larger output at weekly or monthly intervals.

Any item for which there is no use can be disposed of immediately simply by depressing an appropriate key. Items that appear to be of some interest can be pursued at once. Alternatively, the scientist may choose to read off the bibliographic data into his or her own private electronic files for later action. An item viewed in its entirety can also be placed into private files in much the same way that an article may be photocopied and placed in the paper files of an individual.

In the electronic world, the machine-readable file of resources replaces the paper file. But in the private electronic file an item can be indexed in any way, and with as many access points, that the user wishes. The paperless personal file will have infinitely greater search capabilities than the paper files it replaces, and it will occupy virtually no space (since, conceptually at least, a report need exist physically in only one file, its "existence" in other files being achieved through the use of pointers to master files of primary text).

So far we have considered only input to an electronic communication system, dissemination of items within this system, and the building of files of these items. The scientist will also need to search for information—both factual data and text describing particular phenomena of interest. At present, the scientist will seek information of this kind through personal files or conversations with colleagues or consultants. Sometimes (but frequently as a last resort) the scientist will visit a library or other formal information center. In the electronic system, all these approaches to information seeking may be conducted through the same terminal.

The terminal, of course, gives access to one's own information files (and, possibly, the information files maintained by colleagues or by one's department). If these files fail, the terminal will provide an entry point to a vast array of outside sources. Accessible on-line will be machine-readable files that are the electronic equivalents of printed handbooks, directories, dictionaries, encyclopedias, almanacs, and other reference tools. The scientist will also have access to on-line indexes to primary text, presumably built and maintained by those same organizations that provide SDI services. Scientists will be able to use a "widening horizons" approach to their information seeking in this environment, going from personal files to institutional files to national and international resources. And any useful item of data or piece of text that they uncover during the search can, of course, be added rather easily to their personal information files.

But not only *files* will be accessible through the terminal. Human resources will also be available. On-line conversations (in "real time" or somewhat delayed) can be carried out with consultants, professional colleagues, and information specialists located at information centers or information analysis centers (which may, in fact, be 10,000 miles distant). The electronic mailing system can be expected to displace the present mailing system for much, if not all, professional and business correspondence. In the electronic world the distinction between formal and informal channels of communication is likely to be much less distinct, and attempts to meld the two forms (e.g., the formation of information exchange groups) will become much more practicable, through rapid and efficient communication processes, than they are in the present print on paper environment.

In my opinion, there is no real question that completely paperless systems will emerge in science and in other fields. The only real question is "when will it happen?" We can reasonably expect, I feel, that a rather fully developed electronic information system, having most if not all of the features mentioned, will exist by the year 2000, although it could conceivably come earlier.

The implementation of the system will involve the coming together, or rather the deliberate "putting together," of a number of separate services, activities, and experiments already in existence. Major steps towards a paperless system have already occurred through the growth of machine-readable data bases and data banks and the increasing accessibility of these resources through on-line technology.

We can reasonably expect a continued

growth in the number of available data bases, with rapid developments occurring in the social sciences and in the humanities as well as in the sciences, and the achievement of even greater levels of accessibility through the further implementation of information networks. We can also expect to see increasing bodies of primary text becoming available in machine-readable form as more and more publishers convert to computerized operations.

The "editorial processing center," as described by Bamford among others, may provide the opportunity for even small publishers to automate their production processes.[18] At the same time, significant further improvements will undoubtedly occur in computer and communications technologies, and these developments will result in greatly reduced costs for the storage, transmission, and exploitation of textual material in very large quantities.

Computer text-editing capabilities were already quite advanced in 1971 when Van Dam and Rice reviewed the state of the art,[19] and many improvements in this technology have occurred since then. In the business world, "word processing" is replacing "typing," and the paperless office (see, for example, Yasaki[20]) is becoming a reality. Computer conferencing, as described by Price,[21] is developing rapidly, and some business organizations are already relying on this form of communication to replace the conventional mail service for intracompany correspondence. We are also beginning to see the establishment of a few small, experimental "journals" in electronic form.

On-line systems to support the building of personal information files have been available at several universities in the United States for some years. It would not be an exaggeration, then, to say that all the features of the model described could be implemented today if these various technologies and experiments were brought together to form a new science communication system.

I do not wish to give the impression, however, that no problems of implementation exist. Elsewhere, I have identified various technological, intellectual, and social problems of implementation and suggested that this sequence is one of increasing complexity.[22] It is not my intention to repeat the discussion of these problems here. It is sufficient to say that, while some of these problems may appear "thorny," they are certainly not insoluble.

Conclusion

We are moving rather rapidly and quite inevitably toward a paperless society. Advances in computer science and in communications technology allow us to conceive of a global system in which reports of research and development activities are composed, published, disseminated, and used in a completely electronic mode. Paper need never exist in this communications environment. We are now in an interim stage in the natural evolution from print on paper to electronics. Now the computer is used as an efficient means of typesetting, but the resulting publications are still distributed, through the mails, as print on paper. Machine-readable data bases exist side by side with printed data bases but have not yet replaced them. This situation will undoubtedly change.

When on-line terminals are sufficiently commonplace that the great majority of potential users of a publication have ready access to them and when the volume of use of machine-readable data bases is large enough to assume their complete financial support, we will witness the transition to electronic distribution and use of information sources, that is, we will achieve completely paperless systems.

This brings me, at last, to the real point of my paper. Can libraries survive in a largely electronic world? Will they be needed when the raw materials with which they have traditionally dealt are no longer available in printed form but are all readily accessible, on demand, to anyone with a terminal and the ability to pay for their use? If libraries and librarians will be needed, what functions will they perform, and how will they perform them?

Folk, in his description of a future electronic system, suggests that "libraries would also wither away, their historic duty done."[23] It is not my intention to investigate here the credibility of this statement. But a thorough analysis of the potential role of libraries in an electronic society is long overdue.

The profession seems to have its head in the sand. The paperless society is rapidly approaching. Ignoring this fact will not cause it to go away. The profession, if it is to survive, should now be devoting energy to the serious study of how it can adapt to life in this society. Unless it now faces up to the question "Whither libraries?" it will indeed face the prospect of "wither libraries."

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