Technology in Society, Vol. 14, pp. 199–220, 1992
Printed in the USA.

0160-791X/92 $5.00 + .00

Changing Times for Scholarly Communication:

The Case of the Electronic Journal

Andrew Calabrese

ABSTRACT. In 1945, Vannevar Bush described his concept of the future of information storage and retrieval for scientists. His vision has been modified significantly as new developments in computer and telecommunications technology add capabilities beyond what he perceived as possible. The pursuit of a modern, multi-purpose workstation which would enable scholars to create powerful, flexible, and personalized databases remains active. Today, a part of that vision has been translated into the concept of the "electronic journal," a somewhat ambiguous, elusive, and appealing goal to many within the publishing and library and information science communities and among the many other scholars who would use such a tool. This paper provides a history of efforts to develop and institutionalize computer-based systems for scholarly communication, focusing primarily on peer-reviewed scholarly journals. Although it would be an exaggeration to claim that these emerging systems are the cause of proliferating inter- and intra-disciplinary research activity within "invisible colleges," it is noted below how such activity is enhanced by these developments. It suggests that the changes now taking place make it possible to broaden the scope of scholarly communication and perhaps reduce the impact of mainstream journals. However, it also suggests that disciplinary structures have an interest in suppressing or channeling the development of such technology to reduce its potential to subvert disciplinary control.

In Vannevar Bush's famous essay entitled "As We May Think," published in *Atlantic Monthly* in 1945, he anticipated the modern, multi-purpose

Andrew Calabrese (Ph.D., 1988, The Ohio State University) is an assistant professor in the Department of Communication, Purdue University, West Lafayette, Indiana, where he teaches courses on communication technology and society.

The author is grateful to Thomas Hickey of the Office of Research at the Online Computer Library Center, Inc. (OCLC) in Dublin, Ohio, and Stephen Acker of the Department of Communication at the Ohio State University, Columbus, for numerous discussions about the subject of this paper and for commenting on earlier versions.

"scientific workstation" in his description of a personal terminal called "memex" (memory extender). Bush presented a hopeful scenario of the possibility of a machine with extensive information-handling needs to enable scientists to create powerful, flexible, and personalized associational databases:

> A memex is a device in which an individual stores his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.
>
> It consists of a desk, and while it can presumably be operated from a distance, it is primarily the piece of furniture at which he works. On the top are slanting translucent screens, on which material can be projected for convenient reading. There is a keyboard, and sets of buttons and levers. Otherwise, it looks like an ordinary desk.[1]

Bush, who was then Director of the Office of Scientific Research and Development for the US Government, the equivalent of today's National Science Foundation, was concerned about the difficulty that scientists and engineers had even at that time with information management, concluding that "publication has been extended far beyond our present ability to make real use of the record."[2] Not surprisingly, the possibility of resolving this issue through technological innovation remains at the core of a great deal of investment in research, development, and marketing more than 45 years after Bush wrote.

Many forecasts suggest that the nature of scholarly communication may be radically transformed due to the new technical capacities of computer-based information systems.[3] Of course, these scenarios warrant significant skepticism, consistent with Brian Winston's argument that the institutional constraints and pressures on technological development have their way of suppressing a technology's "radical potential."[4] The technological environment for scholarly communication is sufficiently unstable to cause considerable doubt towards hard and fast predictions about the future. Discussions of the seemingly limitless technical potential of computer networking must be moderated with the recognition that a variety of forms of institutional control tend to weigh heavily in suppressing and shaping technological development. Consequently, while it may be enjoyable to some and frightening to others to speculate, it would seem equally if not more fruitful to analyze the institutional contexts in which technological developments occur. What are the interests at stake? Who are the stakeholders? Where does the determining power lie? Answers to these questions are necessary to sustain a meaningful dialogue about the future shape of any technological system.[5] Such questions imply that it is pointless to focus on artifacts without understanding the social relations that constitute and are constituted by them. Furthermore, they imply that the obsessive preoccupation of much of the discourse on the future of technol-

ogy with prediction is misguided. A precursor to understanding what is likely is to understand the nature of the existing controlling factors, such as political, economic, and ideological authority.

This article considers the changes that have been taking place in the nature of scholarly communication as the use of computer and telecommunications becomes widespread. In particular, emphasis is given to the real and imagined impact of computer networking on the publication of peer-reviewed academic journals.[6]

Institutional Foundations of Scholarly Communication

The paper-based system of scholarly journal publishing has functioned as a stabilizing force in directing the growth and flow of codified knowledge in the academy for centuries. Whether that stability will be undermined by the ephemeral qualities of some types of computer-based scholarly communication would seem to be subject to the countervailing influences of peer review standards and of institutionalized structures of knowledge development that go beyond the mere publication of journals. Nevertheless, it is reasonable to assume that some significant changes will occur in knowledge creation and use due to the rapid diffusion of computer-based information and communication systems. The relevance of particular contemporary socio-technical developments can be usefully explained against the backdrop of the institutional contexts in which they are emerging. Thus, the paper-based system of scholarly journal publishing and the present role of "invisible colleges" in scholarly communication are of particular concern below. The political economy of scholarly journals in their paper-based form is the subject of the following brief overview.

Paper-Based Publishing

McDonald and Bush describe two general classes of serial literature: (a) literature subject to peer review and "often written in a technical language or a level of detail which is not familiar to the general reader," its primary function being "to communicate original research findings and/or scholarly writing;"[7] and (b) "other serials," including "newspapers, newsletters, general audience magazines and periodicals, trade magazines, magazines aimed at managers and executives, financial reporting services, abstracts, indexes, and regularly-published bibliographies."[8] Separating these two categories is the fundamentally distinguishing feature of *peer review*, a means of subjecting the work of a scholar to the (typically anonymous) judgments of members of the intellectual community the scholar wishes to reach in a formal public forum. Peer review provides the most widely accepted basis of quality control over the pro-

cess of scholarly publication. Journals published under these conditions provide a measure of assurance to readers that the ideas therein must be taken seriously because some degree of consensus has been reached on the worthiness of those ideas for consideration by targeted intellectual communities and the interested lay public.

The scholarly journals and "other serials" discussed by McDonald and Bush differ not only on the basis of peer review, but also in connection with their modes of production and economic organization. Sanders of the American Chemical Society cites the five major operational costs involved in the production and distribution of scholarly journals in the discipline of chemistry. His illustrations account for costs of production beyond the manuscript stages of writing, reviewing, and editing. They are composition, presswork and binding, paper, postage, and mailing. For a journal with 2,000 subscribers, composition constituted 67% of total costs, whereas for a journal with a circulation of 14,000, composition accounted for 52% of total costs. Overall, costs of production appear volume-sensitive. Similarly, journal revenues appear volume-sensitive. Not surprisingly, larger circulation journals, with their greater access to "mass" markets within scientific disciplines, tend to rely on more advertising. Whereas the journal with 2,000 subscribers acquired only 6% of its revenue from advertising in 1983, the journal with 14,000 subscribers acquired 65% of its revenue through the sale of advertisements. Subscriptions accounted for 70% of the 2,000-subscriber and 28% of the 14,000-subscriber journals, respectively. Other revenue centers, namely, reprints, page charges paid by authors, microform rights, and back issue sales, do not differ markedly.[9] Today, composition costs are likely to have decreased as a function of the ability of authors to submit manuscripts by computer network or by mailing a computer disk. Nevertheless, scholarly journal publishing remains primarily paper-based at the printing and distribution stages.

In the course of ongoing efforts to match supply and demand in scholarly publishing, various private and public sector initiatives have been made to enhance the paper-based system of production and distribution. Apart from personal subscriptions and library use, scholars obtain access to the periodical literature in their fields in a number of ways, including interlibrary loan, article reprints, and a few other less-frequently used services. One of the most advanced of these services is computer-supported interlibrary lending, such as the system operated by the Online Computer Library Center, Inc. (OCLC) in Dublin, Ohio.[10] A reference librarian at one site is able to search the system, which interconnects most academic and numerous public and corporate libraries in the US, and increasingly abroad, to locate libraries that carry the needed item and then place an online request to borrow or copy it. Other options available to scholars with sufficient financial resources include "research-for-hire." Some research companies such as Information on

Demand, Inc. (IOD) in Berkeley, California, will provide a distant scholar with photocopy access to virtually any journal in print. IOD has staff located near major research libraries across the country, and its services may be requested by mail, telephone, or online. Another option is access to various "article clearinghouses," such as University Microfilms International (UMI), which provides photocopy access to the massive journal collection it owns and uses for the primary purpose of marketing microfilm versions of journals to libraries. UMI's Article Clearinghouse is accessible by telephone and through various online information services.[11] Similarly, scientific and technical societies such as the American Chemical Society possess massive journal collections in order to provide abstracting services. They also obtain additional revenue from those collections by offering article photocopying services. As with IOD and UMI, ordering can be done by mail, telephone, or online.

For the scholar whose research expenses are not covered or subsidized, prices for such services such as IOD's and UMI's are not easily affordable. The labor-intensive nature of these services results in high operating costs, which are passed on to users. In the library community, the issue of whether or not to pass on such "user fees" to patrons has long been controversial. The particular point of dispute is whether libraries, most of which rely on some level of taxpayer support, should charge for "public goods."[12] Furthermore, in an age of growing legitimate concern over the distance between information haves and have-nots, there have also been efforts to stress a definition of "freedom of expression" that incorporates the notion of the public's "right to know."[13] In response to such tensions and in the name of wider access to scholarly publications in particular, serious efforts have been made in the past to create a federally funded national periodicals system. The system would have relied on paper-based journals as well as microforms (microfiche and microfilm). An online index and order placement system was to be used, and distribution was to be in hard copy. In 1977, a report was prepared by the National Commission on Libraries and Information Science (NCLIS), which recommended the formation of local, state, and regional library periodicals storage and distribution systems; a national periodicals center (NPC) — perhaps more than one, if warranted; and the use of existing national libraries and other unique collections to back up the first two levels.[14] Following the NCLIS report, the Library of Congress commissioned the Council on Library Resources, Inc. (CLR) in 1978 to provide technical and economic analyses for a national program. CLR recommended the construction of a modular warehouse facility, the acquisition of a massive journal collection, and the development of bibliographic "finding tools" for cataloging and indexing the collection. Relationships with publishers were to be established to ensure copyright protection and to gain their cooperation. Estimated costs at the time for construction of the center were $5.5 to $6.5 million.[15]

In 1979, NCLIS hired the research firm of Arthur D. Little, Inc. (ADL) to evaluate and integrate the 1977 and 1978 reports. ADL expressed concern over whether publishers and libraries would cooperate, and whether the service might not reach technological obsolescence in a short time due to the rapid advancement of electronic systems. ADL asserted that a paper-based system would have minor impact on reducing the heavy burden on interlibrary loan traffic, reprint sales, photocopying within libraries, and photocopying from private subscriptions.[16] As a result of cumulative doubts, the federal government abandoned its interest in an all-purpose, paper-based national periodicals center, and the concept was not realized. According to Biggs, the lack of action should be attributed to the absence of decisive leadership both in Congress and in the library profession.[17] However, it is equally plausible that the many technological and organizational uncertainties, and the federal government's increasing tendency to favor private-sector initiatives, are the reasons.

From the perspective of journal publishers, a bureaucratically controlled national periodical system had its attractions, since publishers are concerned about limiting the potential means by which scholars can circumvent payment for access to and use of journals. The wide use of photocopying technology has made it possible for scholars to become more selective about the number of journals to which they subscribe, thus threatening the flow of subscription revenues. The benefit scholars enjoy is the convenience of obtaining copies of selected articles from publications that only infrequently publish articles of relevance to their own research. As a result, scholars can achieve greater breadth in their coverage of relevant literature while not suffering from the burdensome costs of numerous subscriptions. While this situation is appealing to researchers, publishers fear the loss of revenue when their subscriber base is primarily libraries.

One of the private sector's efforts to provide publishers with compensation for this perceived loss of revenue has been the formation of the Copyright Clearance Center (CCC). The CCC was established in 1977 following passage of the US Copyright Act of 1976, and it exists for the purpose of providing a means for publishers to collect royalties from users who require more than "fair use" in photocopying. By 1987, the CCC had registered approximately 12,000 publications by about 1,200 publishers, and more than 2,000 corporations, information brokers, academic and research libraries, government agencies, and others were registered as users of the service.[18] The CCC offers a means for publishers to capture additional revenue while saving the user of copyrighted materials from having to seek permission directly from several publishers when "fair use" is exceeded.

From an economic standpoint, the concept of a copyright clearance center seems flawed because there is no direct financial incentive for libraries to monitor carefully the use of photocopying equipment on

behalf of publishers and the CCC. From a library's perspective, the active involvement in policing patrons on behalf of copyright holders seems an unduly burdensome task. The same argument applies to the monitoring of commercial copy centers. Consequently, the paper-based CCC concept may be ineffective in enabling publishers to control the situation brought on by photocopying. Furthermore, since most public and academic libraries rely heavily on taxpayer support, it is a questionable use of public funds to pay library personnel to channel the flow of revenue from patron to commercial publisher. One "solution" publishers have begun to explore is the possible shift toward electronic document delivery as a complement to print-based journal production and distribution, which would enable them to maintain greater control over revenue flows. Although it is arguable that worry over the impact of new technology on control over copyright should be at the forefront of university efforts to reconceptualize modes of communication among scholars, it nevertheless is a central factor from the perspective of powerful investors in system development. At the same time, a very different set of concerns arise from the perspective of scholars and academic institutions.

The Invisible College and the Velocity of Information

To understand the broader framework in which changes in scholarly communication are occurring, it is useful to examine the impact on institutional foundations of the academic "discipline." Are academic disciplines threatened with extinction due to the inability of bureaucratic structures to respond to the felt need among scholars to exploit available, flexible, and rapid communication resources? Where does such a threat lie, if it indeed exists? Campbell views present disciplines as "arbitrary composites" and academic departments as the products largely of historical accident.[19] Other sociologists of knowledge echo Campbell in concluding that all disciplines have sets of boundaries that serve bureaucratic functions. For Chubin *et al.*,

> . . . disciplines represent historical, evolutionary aggregates of shared scholarly interests. These aggregates gain legitimacy in the university as "departments." As organizational niches, departments bureaucratize knowledge by subject matter and stake a claim to research and train students in it.[20]

Saxberg *et al.* note that interdisciplinary research activities and centers generally do not enjoy the same degree of commitment and support from university administrations as do academic departments, and they observe that the university reward system rests within the departmental structure.[21] Hagstrom notes that conformity to disciplinary structure is maintained by the use of formal sanctions such as the denial of appointments or access to communication channels.[22] As clear as the incentives to obey disciplinary boundaries seem, these observations focus mainly on

threats to formal structures. However, those boundaries are penetrated through the oblique networks of scholars now known by many as "invisible colleges." The term "invisible college" was coined in mid-17th century London by a small group of progressive scientists and philosophers who are said to have sought refuge from the political turmoil of English civil war and to have created the Royal Society.[23] Today, the term is applied to groups whose "invisible" feature is due more to the lack of institutionalization and bureaucratic control than to any clandestine purpose.[24]

Price popularized the current meaning of the term "invisible college" in his analysis of changes in the nature of scientific research activities, particularly the relative increase in the strength of informal networks and the acceleration in the reporting of scientific findings:

> We [scientists] tend now to communicate person to person instead of paper to paper. In the most active areas we diffuse knowledge through collaboration. . . . We publish for the small group, forcing the pace as fast as it will go in a process that will force it harder yet. Only secondarily, with the inertia born of tradition, do we publish for the world at large . . . It has made the scientific paper, in many ways, an art that is dead or dying.[25]

Price's observation reflects how participation in an invisible college is a more rapid means than journal publication for "affluent scientific commuters" to reach their peers. However, for better or worse, it is also a potential means of circumventing the peer review process. Part and parcel of the explanation Price offers is the recognition he gives to the fact that scientists increasingly tend to view their research problematics in narrower terms than those circumscribed by traditional academic disciplines. Thus, for Price, an invisible college exists not only to enhance the speed of scientific communication, but also to provide a more focused forum for the sharing of research interests. Similarly, Kuhn notes that in order to identify scientific communities at the level where shared research goals occur "one must have recourse to attendance at special conferences, to the distribution of draft manuscripts or galley proofs prior to publication, and above all to formal and informal communication networks including those discovered in correspondence and in the linkages among citations."[26] Today, the scientific study of scientific communities through "bibliometric" or citation analysis is one of the means used to validate the existence and intellectual interdependencies of invisible colleges.[27] Although it would be of highly questionable ethics and legality, the analysis of interpersonal communication patterns on computer networks would seem likely to reveal similarities.

Invisible colleges serve as the functional alternative to broadly defined disciplines at a time when it is impossible to possess any significant depth of knowledge about an entire "discipline." Campbell argues that "unidisciplinary competence" is a myth because the present degree of specialization and the sheer volume of information that falls within the boundaries of institutionalized disciplines outstrips the ability of individ-

uals to master it. Consequently, he argues that a felt need to maintain competence across a discipline is a misuse of human resources:

> The temporary disciplinary breadth transiently achieved in graduate school is of course not undesirable — the objection here is rather to the repetitious duplication of the same pattern of breadth to the exclusion of other breadths equally relevant but *organizationally unsupported* [emphasis added].[28]

While rejecting the goal of unidisciplinary competence, an ideal that seeks to make all students conceptually and methodologically interchangeable, Campbell promotes the pursuit "novel narrowness." He advocates the development of research specialties that overlap with one another in order to build towards collective rather than individual competence. From this perspective, the deep knowledge of the specialist who is focused on the problematics of his or her invisible college is cultivated to extend the broad knowledge of the collective, and the concern with disciplinary conformity is secondary.

The scholarly journal is an important consideration within the larger context of arguments over disciplinary boundaries, for journals provide the visible, tangible evidence of a discipline's achievements and contributions. For purposes of discussing institutional power and its influence on knowledge development, interdisciplinary journals tend to be treated as "fringe" publications. This status does not suggest that interdisciplinary journals are qualitatively inferior to mainstream disciplinary journals, nor that interdisciplinary journals categorically are unfocused. Interdisciplinary journals are more or less "important" only to the extent that they are institutionally so accorded. In some cases, they carry exceptionally high prestige across disciplines. Arguably, much of the most interesting and ground-breaking interdisciplinary work in the sciences and the humanities, some of which does receive institutional support through research institutes, special grants, and other means, is significant largely because it pushes harder at the frontiers of institutionally defined knowledge. To this end, interdisciplinary journals are valuable for identifying and mapping the spaces between the tectonic plates of institutionally maintained disciplines, sometimes resulting in the fruitful transcendence or novel integration of seemingly unrelated domains within or between disciplines. For this reason, Campbell's portrait of the optimal organization of scholarly inquiry as overlapping but unique specialties offers a useful alternative to bureaucratic rigidity. Nevertheless, institutional reward systems, including publication in mainstream journals, continue to provide significant incentives for scholars to adhere to the traditions of established disciplines. In this regard, whether interdisciplinary journals fill specialized needs is less important in discussing prevailing institutional realities of knowledge development than potentially countervailing disciplinary control over institutional levers such as tenure and promotion, access to journals,

availability of research funds, etc. Although on the one hand, as Campbell argues, it is increasingly necessary for scholars to pursue "novel narrowness" characteristic of invisible colleges in order to offer unique contributions, on the other hand, the power of well established disciplines is potentially undermined.

Invisible colleges are more fleeting and permeable than formal disciplines because they are not weighted down by the apparatus of bureaucratized knowledge. They also appear to be problem-centered, not discipline-centered. The basic argument made by those holding this perspective is that real problems do not necessarily obey the boundaries of discipline-shaped boxes.[29] Thus, despite the lesser degree of formal support, there is significant growth in other forms of university support for interdisciplinary research,[30] illustrated recently by the growing support for research in biotechnology, artificial intelligence, and other hybrid fields. However, the distinction between "problem centered" and "discipline centered" inquiry does not necessarily imply a lack of theoretical underpinnings or a lack of concern with theory development for the former. As Dudley Shapere notes, defining the scope of a scientific domain is itself a fundamental act of theorizing, since it seeks to posit the presence of a set of relationships among elements within that domain.[31] The unified research problematics that characterize participation in invisible colleges seem to imply that these groupings do in fact cohere along theoretical lines.

What invisible colleges promote is exactly what is implicitly discouraged by disciplinary boundaries: the relatively unrestrained contact needed to theorize about domains that may or may not fit within traditional disciplinary boundaries. Exactly how unrestrained such contact is or can be without sacrificing productive research programs is a broader question, an honest answer to which would have to confront political as well as scientific matters. Bourdieu argues that a principle issue at stake in defining disciplines is *scientific authority*, defined inseparably as both technical capacity and social power.[32] These features play a fundamental role in the establishment and maintenance of disciplinary boundaries. The motivation for being a member of an "invisible college" in the 17th century has metaphorical significance today. Academic administrative structures have their own potentially stifling effect, maintained in large part to sustain consistent performance criteria based on the instructional and evaluation needs of complex bureaucratic institutions. Large academic associations, established departmental structures within the university, and flagship association journals are among the major forces contributing to the maintenance of a discipline's traditions. While an argument is not being advanced here to abolish these structures, it is clear that the question of detrimental effects on knowledge creation and use due to bureaucratic control is a subject of considerable argument within the sociology of knowledge. At the same time, the small interdisciplinary

conference of like-minded specialists and the "virtual networks" of the same individuals have become commonplaces, suggesting that disciplinary apparatus are not as stifling as some may fear. It is easy to see how such informal contacts are extended and maintained through the widening use among scholars of information-age tools such as computer networks and facsimile machines.

Electronic communication technology now is used in the process of "forcing the pace" of knowledge development, perhaps beyond what even Price anticipated.[33] Nevertheless, this technological development does not occur in a vacuum. Winston notes that there is always a tendency for the "radical potential" of emerging communication technologies to be suppressed or channeled by the weight of institutional control.[34] For example, in the case of scholarly publishing, research productivity tends to be measured primarily at the formal level, where institutional reward structures historically have placed the greatest emphasis. Based on this logic, academic institutions arguably will either find a way to prevent the emergence of technological applications that threaten those structures or they will channel its development in such ways as not to upset the existing power balance. Clearly, the emergence of the computer and telecommunications as vital tools for scholarly communication has not been suppressed. Whether it is being channeled to mitigate the possible threats to institutional control may only be revealed through hindsight. However, from our present vantage point it remains useful to examine the present range of developments in electronic communication among scholars, as well as the attendant political issues. I do so below with the admittedly specific purpose of stressing the impact — real and imagined — of emerging technological systems for communication on the enterprise of *formal*, mainly peer-reviewed, scholarly publishing.

New Machines and Changing Times

Vannevar Bush's vision of "memex" did not anticipate the development of computer networks that enable scholars to extend their interpersonal contact with colleagues on a global basis. More recently, scenarios of what the future of computer communication might be like reflect a greater awareness of the possibilities.[35] Such developments are changing how many scholars communicate, both formally and informally. Although it may seem difficult to conceptually distinguish formal and informal communication when the same system may be used for both, it is not an impossible task. The following discussion of the role of emerging media systems for scholarly communication provides such distinctions along with a primary emphasis on the formal publication outlet known as the peer-reviewed scholarly journal.

Invariably, information-age visions of the processes of manuscript submission, review, and editing entail the use of telecommunications for

quick turnaround. King *et al.* describe well the essential elements that appear to be common in those scenarios:

> In the electronic journal system, articles will be prepared by authors using sophisticated text-editing systems. Article preparation may include joint writing of text through teleconferencing systems in which immediate peer review is possible, comments are made, and specific research questions can be answered. . . . The digital form of the unreviewed manuscript will be directly transmitted electronically to a publisher. The publisher will electronically transmit the manuscript to a subject editor, who will read the text by CRT or printout and make electronic notes concerning editorial content and quality. The subject editor may choose appropriate reviewers using a computer program that matches the profile of potential reviewers with the topics covered in the article. Other computer-stored information will be used to help screen reviewers, such as by affiliation and relationship to the authors, status of the most recent review, frequency of reviews, timeliness of response of previous reviews, and quality of reviews. The reviewers will respond to editors, and editors in turn to authors, by telecommunication, comparable to current teleconferencing processes for business purposes, address listings, and other such activities.[36]

Although this scenario may seem fanciful to scholars not socialized in the use of computer networks, electronic document exchange has been a vivid reality for decades for informal exchanges. The following discussion examines the recent history of efforts to realize various aspects of such a vision, particularly those developments most relevant to the emergence of a system of peer-reviewed electronic journals.

The Electronic Journal: A Technical and Market Primer

Estimates of operational costs for publishing an electronic journal, produced in tandem with its print counterpart, would require adding the cost factors of processing, storage, and telecommunications. However, it is not unreasonable to expect some journals to be available only in electronic form in the future, thus eliminating cost factors associated exclusively with paper-based systems, such as presswork, binding, paper, and postage. The manuscript submission, review, and editing of a journal article can now be handled via telecommunications, potentially more cheaply and in less time than the present economics of paper-based systems allow. One effort to streamline the production process for paper-based publishing which applies equally to electronic journal publishing is the development and increasing use of a standardized "electronic manuscript" format. The Association of American Publishers' (AAP) "Electronic Manuscript Project" was initiated for the purpose of establishing an electronic "standardized generalized markup language" (SGML) which authors and editors would be able to use. The SGML is the product of an AAP-sponsored research effort initiated in 1983 involving authors and library and publishing groups throughout the world.[37]

Along with developments to standardize the processes of electronic manuscript production is the increased availability of means by which manuscripts may be transmitted electronically. Computers and telecommunications increasingly are used to support informal fora for scholars with special interests through such means as electronic mail, document delivery (including manuscripts), and electronic bulletin boards. Crude experimentation in the US with computer-based systems for such informal scholarly communication dates as far back as the initial development of the Department of Defense's Advanced Research Project Agency Network (ARPANET) in 1968-69. By 1975, ARPA had installed a network of 50 host computers at 38 sites, including Hawaii, Norway, and England. Today, the ARPANET has been divided into a general access network by the same name, and MILNET, which is used for higher-security military purposes. The ARPANET user community shares data, algorithms, and ideas, combining publishing and computer conferencing in one system. Another ongoing US project of historical importance is the Electronic Information Exchange System (EIES), described in detail by Hiltz and Turoff.[38] In addition to these networks, the academic and research community is served by BITNET, which is available at most universities in the US, as well as in many other countries throughout the world. Such networks can be used not only in manuscript production but also as journal *delivery systems*.

Other computer-based developments in journal delivery include facsimile transmission, which is used not only for point-to-point communication, but also for making images of journal pages as a step in storing them on optical disks. University Microfilms International (UMI) recently began marketing to libraries an optical disk system which provides access to facsimile images of the full text of 150 of the most frequently used general interest periodicals available in microform (microfilm and microfiche).[39] Facsimile scanning, combined with optical disk storage, is likely to displace the use of microforms as archival media because of superior image quality, greater random access capability, and possibly the longer-term archival value. Optical disk technology is now used in efforts to preserve and disseminate information created or used by several federal agencies, including the Nuclear Regulatory Commission, the Smithsonian Institution, the Library of Congress, the National Library of Medicine, the Bureau of the Census, the US Geological Survey, the Department of Defense, and various other federal agencies.[40] The National Library of Medicine's (NLM) massive preservation efforts include experimentation with the development of facsimile-based systems using optical disk storage technology to archive journal literature in the biomedical sciences.[41] In conclusion, facsimile-based systems function well for archival purposes, but they lack the long-term promise of systems that rely on a foundation of "character-coded" text. The latter are more powerful for searching the full text of a document and more flexible as far as display and printing are concerned. In contrast, the

smallest searchable unit in a database of facsimile images is the page, and text searching is limited to indexes and abstracts to the articles themselves.[42]

Today, a number of US companies are experimenting with and/or commercially marketing fully searchable (character-coded) databases as a secondary outlet for peer-reviewed journals. One R&D leader has been the Online Computer Library Center, Inc. (OCLC), whose efforts in this area began in 1979 and have continued to the present, including the prototyping of sophisticated storage and retrieval systems that rely on "hypertext" search capabilities.[43] OCLC has done technical and market experimentation with major scientific journal and encyclopedia publishers, including the American Chemical Society and John Wiley & Sons.[44] However, OCLC currently is not competing in the commercial market, whereas several "online utilities" or "host systems" in the US (e.g., Dialog, BRS, STN) are doing so by carrying databases containing the full text of academic journals that have long been available in paper. Today, 18 journals of the American Chemical Society, five chemistry journals from John Wiley & Sons, ten from the Royal Society of Chemistry, and science journals from other publishers are marketed online by STN International.[45] This brief list does not even scratch the surface of the many fully searchable (as contrasted with facsimile systems with limited search capabilities) full text databases now available online in the US[46] Included in this growing number are periodicals published only in online form, but few in that category are peer-reviewed.

In the past several years, a number of electronic journal projects have been initiated outside the US, particularly in Western Europe. The European Commission's DOCDEL document delivery program supports ten projects, of which three involve simply the transfer of documents, four involve the publishing of electronic-only periodicals, two are development projects, and one involves so-called "invisible college," designed for the purpose of informal information exchange such as the sharing of "grey literature" (unpublished papers and reports).[47] Another experimental European project, Automated Document Delivery over Networked Information Systems (ADONIS), carries the full text of 219 biomedical journals from ten publishers, and is distributed by optical disc. The system, which began in 1980, is available to participating libraries in Europe, Australia, Japan, and North America.[48] Compared with the US, European national governments and the EC are more heavily involved in financing and coordinating private-sector efforts in electronic document delivery. The lack of similar government involvement in the US may be explained in part by the absence of a centrally instituted science and technology policy for purposes other than military applications, but also perhaps by the greater commercial competition in the US, even without federal support. Nevertheless, the federal government has been involved in developing electronic storage and delivery systems for

its own purposes, including inter-agency communication and the public dissemination of government information.[49] As noted above, the federal government is also involved in financing preservation programs using facsimile technology. Despite this difference between the US and Western Europe, it would be hasty to conclude that the private sector of the US is disadvantaged in this area in comparison with its European counterpart. It is generally recognized that advances in high technology that are put to specific purposes by the US government, particularly the military and NASA, are sometimes sources of significant commercial opportunity as they are subsequently channeled into private-sector applications.[50] This tendency is aptly illustrated by pioneering status generally granted to the ARPANET.

Shifting Institutional Boundaries

Thus far, we have seen that existing configurations of computer networks for scholarly communication make possible the integration of formal and informal dimensions of the enterprise of peer-reviewed journal publishing. This integration is of more than passing significance to institutionally maintained scholarly journals. Compaine and associates have observed that a new medium often triggers changes across existing media, resulting in shifts in the institutional boundaries dividing media systems. They suggest that instead of emphasizing the "substitution effect" of one technological system on another, a more useful approach to understanding the changes taking place would be to look at the "dissolution of old groupings and crystallization of new."[51] Widely recognized in this regard is the lesson learned from the misfortune of the railroad industry, which was unsuccessful in its attempt to prevent the emergence of an interstate trucking industry, and which declined because it failed to recognize that it was in the business of freight transportation, not railroads. This is not a novel thought, although it is one which warrants reinforcement for a variety of reasons. The enterprise of the production and distribution of knowledge, however transformed, remains in need of service.

The continued computerization of scholarly publishing introduces many new capabilities for storage and retrieval. For example, in research areas where significant amounts of supporting data previously had not been published due to the bulk and associated journal printing costs, such data could be attached as an electronic appendix at relatively low cost on an online or disk-based system. Given the decreasing cost of storage and distribution, arbitrary document length restrictions need not be as much of a concern as they had been in a paper-based publishing environment. Furthermore, the absence of publishing costs specific to a paper-based system (particularly paper and distribution/postage) may make it possible for new "virtual" journals to be initiated by a wider

range of scholars at lower financial risk. The search capabilities of electronic publishing also enable users to treat published literature differently, as readers are able to search across many journals at once and to jump about using hypertext features.[52] A consequence of this practice may be that the journal "issue" may eventually become an artifact that is irrelevant in an electronic publishing environment. The independent unit of publication for electronic journals could shift away from the journal issue and be replaced by some other unit, such as the individual article, connect time, or scope of access to a database (as in "tiered" access to cable television). From an end user's perspective, electronic systems potentially offer powerful storage and retrieval capabilities, but from a publisher's perspective this means reconceptualizing the nature of revenue flow, possibly resulting in some publications being available only in electronic form. Recognizing this trend, many scholarly publishers have closely examined the ramifications of electronic publishing technology for their industry and their individual firms.[53]

Today, many scholars regularly pay for what are known as "selective dissemination of information" (SDI) searches of computer databases. By designating and storing a profile of keywords to be used in searching online indexes, abstracts, or full text databases, scholars monitor developments across a large number of publications in their fields of interest, extending well beyond the range of access that is affordable by possessing a personal collection of the same journals and with increased efficiency compared with scanning paper-based journals. As Senders suggests, from a researcher's perspective, the major advantages of online searching is that it makes it possible to locate particular information that previously required much greater effort through manual searches of paper-based indexes and journals.[54] By the same token, it remains possible not only to scan databases regularly by using an established SDI profile, but also to "browse" electronically in various ways (e.g., by keyword, author, publication, subject, call number, etc.).

Clearly, there is cause for concern from various perspectives over the diffusion of electronic publishing for scholars. With the emergence of electronic journals, a variety of barriers may emerge for individual researchers, including lack of access to print journals in the library, the high cost of electronic access, and the forced adoption of electronic versions through significant price differentials, or the complete elimination of print alternatives. While all of these concerns are legitimate, they may be exaggerated when weighed against the vested interests publishers have in matching the conditions of supply and demand. Perhaps some of this tension will be offset by financial and technical innovation by academic libraries. While the integration of electronic publishing into the mainstream of scholarly communication may require a different financial relationship between publisher and reader, the relationship between libraries and end users may change as well. Today, some library budgets

are used in part to subsidize the electronic information needs of patrons, primarily to search abstracts and indexes and, to a lesser degree, to less widely available full-text databases. In the future, it may be reasonable to expect university libraries increasingly to provide financial support for scholars to have electronic access to online periodical collections available in local and remote storage locations. In deciding to do so, libraries are able to mitigate some collection maintenance costs, which becomes increasingly attractive as available storage space for paper-based journals becomes more limited and expensive to provide. Compaine envisions a situation where "[m]anagers will have to explain the need to shift some funds from asset acquisition in the form of books, to expense categories for communications and data-base services."[55]

Electronic journals may be perceived as a threat to libraries, possibly rendering bricks and mortar somewhat superfluous, although one should be cautious about placing bets. The use of electronic journals does not imply the ultimate obsolescence of libraries as we know them, nor does it imply the obsolescence of the skilled reference librarian who is trained to know about a wider range of print and electronic alternatives and how best to exploit them. Rather, it simply implies that the demand for a journal, and whether it is available online, should be considered when a library is evaluating its subscription list. In essence, an electronic journal system can be seen as one more "library" among members of an interlibrary loan system. Perhaps what may occur is that, for routine access to some databases, the library will shift its current role as physical intermediary and act increasingly as a *fiscal* intermediary in its capacity as — to use a jargon phrase — a "library without walls." Many scholars now routinely search familiar databases from a variety of locations, including the library, the office, and the home. In an age of expanded telecommunications, it is likely that an increasing number of scholars will want to minimize the necessity of having to physically go to a library and instead make more efficient use of their office workstations, regardless of where they are located.

It is not clear what the dominant organizational structure for the publishers of scholarly journals will or, more importantly, should be. At the most general level, it would seem likely that journals will be available through one or more commercial "information utilities," as is presently the case. Such services as CompuServe, Dialog, and Lexis, all of which can be accessed nationally via packet-switched networks, are possible models. Although their pricing structures differ, they function similarly in that they provide an operating system through which users have access to the offerings of multiple publishers. Of course, another option would be for publishers to market their information directly via packet-switched, long-distance telecommunication networks. Another option, and one which is not mutually exclusive of the others, is the distribution of information by optical disk by utility brokers or by individual publishers.

Although there are illustrations of experiments with peer-reviewed electronic journals, significant problems remain in dealing with a new sort of environment for editorial coordination and in seeking institutional legitimacy.[56] Meanwhile, one reasonable concern lies with the possible weakening or abandonment of rigorous peer review processes. Well known cases of the bypassing of peer review to disseminate scientific discoveries directly to peers and to the public have heightened fears among many about the future integrity of the processes of disseminating scientific information.[57] Given a technological environment in which a scientist can widely disseminate information about a discovery without peer review, will the competition to publish findings quickly lead more scientists to take such an option as a first course? Along with the potential undermining of boundaries between formal and informal channels of scholarly communication, the use of computer networks may also contribute to the undermining of boundaries between academic disciplines. Since computer networking does not require adherence to disciplinary structures, Price's predictions about the fossilization of print-based disciplinary journals are gaining in support.[58]

Conclusions

Socially significant technical changes in the production and distribution of periodical literature are occurring on two fronts. First, the computerization of the process of electronic manuscript submission, review, and editing is proceeding steadily, and with growing commercial support. The technical and organizational developments occurring here indicate a progressive movement toward a long-term reduction in the flow of paper in the process from manuscript to final copy. Second, not only are the processes of document production becoming computerized; so are the processes of document distribution. Examples of this include the increasing number of systems now offering the full text of scholarly journals via telecommunications for remote access and on optical disk for local retrieval.

It is clear that there will be continued movement in the direction of computerizing not only informal but also formal scholarly communication through the publication of scholarly journals. However, one should not treat electronic and print journals as "strict analogs," and the discussions of technological developments provided above implicitly warn against that pitfall. Regardless of the appropriateness of such analogies, for a variety of technical and institutional reasons it is doubtful that the peer-reviewed electronic journal will be developed rapidly. While some peer-reviewed online journals do now exist, they appear more as novelties for technophiles than as widely used operational systems. In the long run, it seems likely that we will see growth in this area as the social

and economic cost-benefit ratios of electronic versus paper-based storage and retrieval become more attractive to interested parties. This clearly is the will of a growing number of journal publishing houses and online utilities. Forecasting when particular developments will occur and how they will be manifested is, of course, a risky business mainly because it is too difficult to assess the degree and nature of resistance to change. All parties involved in the increasingly computerized system of scholarly communication, which include scholars, commercial publishers, online vendors, and academic libraries, are interested in tempering emerging technological capabilities to suit existing or desired social relations and administrative concerns. Of course, it would be foolish to assume that the various parties share the same goals, and there also is little reason to assume that there is unanimity within these groups. For example, degree of loyalty to mainstream journals may be lower among younger scholars who foresee a greater number of options for disseminating the results of their research than for senior scholars who have invested more heavily in those journals.

Arguably, knowledge development and not institutional structures should be the primary concern in considering the implications of technological change for scholarly communication. However, this is not a defense of academic anarchy, but rather an examination of real and potential limits of institutional flexibility. In the relative absence of demands for loyalty to institutionalized disciplines which participation in invisible colleges implies, one is more likely to test the borderlands. Whether this bodes well for the future of higher education is a subject on which reasonable minds can differ. Arguably, bureaucratically maintained disciplines are one, but perhaps not the only or best, means for promoting the growth of knowledge. Consequently, the funding and administration of scientific research, at least in selected areas, appears increasingly to adhere to the principle that the baby of knowledge development need not be thrown out with the bath water of institutional rigidity. Whether this perspective signals a threat to systematic inquiry along disciplinary lines and, more importantly, to theoretical development, is a question that perhaps tests the adaptiveness of academic structures, and it is a question likely to be asked more frequently as the academy is held increasingly accountable to public and private funding sources. It is beyond the scope of this article to confront the full range of dialectics about the future of academic disciplines. Nevertheless, it is clear that the technological developments discussed above must figure significantly in that discourse. Although the focus of this paper — the diffusion of electronic journals — and the more general subject of computer mediated communication hardly constitute a sufficient basis for explaining the future directions of scholarly communication, they do comprise an increasingly necessary one.

References

1. V. Bush, "As We May Think," *Atlantic Monthly* (July 1945), p. 107.
2. *Ibid.*, p. 102.
3. See R. L. Ackoff, T. A. Cowan, P. Davis, M. C. J. Elton, J. C. Emery, M. L. Meditz, and W. M. Sachs, *Designing a National Scientific and Technological Communication System* (Philadelphia: University of Pennsylvania, 1976); S. R. Hiltz and M. Turoff, *Network Nation: Human Communication via Computer* (Reading, MA: Addison-Wesley, 1978); F. W. Lancaster, *Toward Paperless Information Systems* (New York: Academic Press, 1978); and D. W. King, D. D. McDonald, and N. K. Roderer, eds., *Scientific Journals in the United States* (Stroudsburg, PA: Hutchinson Ross, 1981).
4. B. Winston, *Misunderstanding Media* (Cambridge, MA: Harvard University Press, 1986).
5. L. Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge: MIT Press, 1977); D. F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism* (New York: Oxford, 1979); D. MacKenzie and J. Wajcman, eds., *The Social Shaping of Technology* (Philadelphia: Open University Press, 1985); and F. Webster and K. Robins, *Information Technology: A Luddite Analysis* (Norwood, NJ: Ablex, 1986).
6. Because the technological changes under consideration in this article are significant for all scholars, and not only scientists and engineers, the term "scholar" is used as a convenience to refer to members of all professions that rely on peer-reviewed academic journals. No attempt is made to elide the differences in the patterns of knowledge production and use among these distinct groups. More specific groups such as "scientists" are so labeled when it is warranted.
7. D. D. McDonald and C. G. Bush, Libraries, Publishers and Photocopying: Final Report of Surveys Conducted for the United States Copyright Office (Rockville, MD: King Research, 1982), s. 4, p. 3.
8. *Ibid.*, s. 4, p. 4.
9. H. J. Sanders, "Troubled Times for Scientific Journals," *C & EN* (May 30, 1983), pp. 31–44.
10. OCLC maintains the world's largest online database of bibliographic records, contributed to daily by its members. The database serves several functions for OCLC members, including providing a streamlined method of cataloging acquisitions and a backbone to the world's most comprehensive telecommunications-based interlibrary loan network.
11. A. Lucas and K. Y. Marcaccio, eds., *Encyclopedia of Information Systems and Services*, 7th ed. (Detroit, MI: Gale Research Company, 1987), p. 856.
12. In discussing the controversial question of library treatment of online information services as public goods, Gell argues that user charges for public goods are not new, and she cites the use of bridges, highways, hospital, and health services, and public utilities, all of which depend on user fees. M. K. Gell, M. K., "User Fees I: The Economic Argument," in D. W. King, N. K. Roderer, and H. A. Olsen, eds., *Key Papers in the Economics of Information* (White Plains, NY: Knowledge Industry, 1983), pp. 154–158. Gell also argues that libraries are justified in charging users for searches of computer databases, particularly if not charging would require the reallocation of resources away from other library services. M. K. Gell, "User Fees II: The Library Response," in D. W. King, N. K. Roderer, and H. A. Olsen, eds., *Key Papers in the Economics of Information* (White Plains, NY: Knowledge Industry, 1983), pp. 159–62.
13. T. I. Emerson, "Legal foundations of the right to know," *Washington University Law Quarterly*, Vol. 1976, no. 1 (1976), pp. 1–24. See also T. I. Emerson, *The System of Freedom of Expression* (New York: Vintage, 1970).
14. National Commission on Libraries and Information Science, *Effective Access to the Periodical Literature: A National Program* (Washington, DC: NCLIS, 1977), p. 1.
15. Council on Library Resources, *A National Periodicals Center: Technical Development Plan* (Washington, DC: Library of Congress, 1978).
16. Arthur D. Little, *A Comparative Evaluation of Alternative Systems for the Provision of Effective Access to Periodical Literature: A Report to the National Commission on Libraries and Information Science* (Washington, DC: NCLIS, 1979). See also C. D. Gull, *The National Periodicals Center Concept Reconsidered: Alternatives and Costs* (Washington, DC: National Technical Information Service, 1979).
17. M. Biggs, "The Proposed National Periodicals Center, 1973-1980: Study, Dissension, and Retreat," *Resource Sharing and Information Networks* (Spring-Summer 1984), pp. 1–22.

18. Lucas and K. Y. Marcaccio, (eds.), *Encyclopedia of Information Systems and Services*, p. 210.
19. D. T. Campbell, "Ethnocentrism of Disciplines and the Fish-Scale Model of Omniscience," in M. Sherif and C. W. Sherif, (eds.), *Interdisciplinary Relationships in the Social Sciences* (Chicago: Aldine, 1969), pp. 328–348.
20. D. E. Chubin, A. L. Porter, F. A. Rossini, and T. Connolly, *Interdisciplinary Analysis and Research* (Mt. Airy, MD: Lomond, 1986), pp. 4–5.
21. B. O. Saxberg, W. T. Newell, and B. W. Mar, "Interdisciplinary Research: A Dilemma for University Central Administration," *SRA Journal*, Vol. 13 (Fall 1981), pp. 25–43.
22. W. O. Hagstrom, *The Scientific Community* (New York: Basic Books, 1965).
23. C. Webster, "New Light on the Invisible College: The Social Relations of English Science in the Mid-Seventeenth Century," *Transactions of the Royal Historical Society, Fifth series*, Vol. 24 (1974), pp. 19–42.
24. D. Crane, *Invisible Colleges: Diffusion of Knowledge in Scientific Communities* (Chicago: University of Chicago, 1972); and D. E. Chubin, *Sociology of Sciences: An Annotated Bibliography on Invisible Colleges*, 1972-1981 (New York: Garland, 1983).
25. D. J. de Sola Price, *Little Science, Big Science* (New York: Columbia University, 1963), p. 91.
26. T. S. Kuhn, *The Structure of Scientific Revolutions*, 2nd ed. (Chicago: University of Chicago, 1970), pp. 177–178.
27. Y. Elkana, J. Lederberg, R. K. Merton, A. Thackray and H. Zuckerman (eds.), *Toward a Metric of Science: The Advent of Science Indicators* (New York: John Wiley and Sons, 1978); E. Noma, "Untangling Citation Networks," *Information Processing & Management*, Vol. 18, no. 2 (1982), pp. 43–53; E. C. White, "Bibliometrics: From Curiosity to Convention," *Special Libraries*, Vol. 76, no. 1 (Winter 1985), pp. 35–42; H. Small, "The Synthesis of Specialty Narratives from Co-Citation Clusters," *Journal of the American Society for Information Science*, Vol. 37, no. 3 (May 1986), pp. 97–110; and C. L. Borgman, C. L., (ed.), *Scholarly Communication and Bibliometrics* (Newbury Park, CA: Sage, 1990).
28. Campbell, "Ethnocentrism of Disciplines," pp. 332–333.
29. J. T. Klein, "The Evolution of a Body of Knowledge: Interdisciplinary Problem-Focused Research," *Knowledge: Creation, Diffusion, Utilization*, Vol. 7, no. 2 (December 1985), pp. 117–42; and A. Porter and F. Rossini, "Multiskill Research," *Knowledge: Creation, Diffusion, Utilization*, Vol. 7, no. 3 (March 1986), pp. 219–46.
30. Chubin *et al.*, *Interdisciplinary Analysis and Research*.
31. The argument by Shapere was made in a symposium discussion, transcribed in F. Suppe (ed.), *The Structure of Scientific Theories* (Urbana, IL: University of Illinois, 1977), pp. 525–533.
32. P. Bourdieu, "The Specificity of the Scientific Field and the Social Conditions of the Progress of Reasons," *Social Science Information*, Vol. 14, no. 6 (1975), pp. 19–47.
33. Price, *Little Science*, Big Science, p. 91.
34. Winston, *Misunderstanding Media*.
35. For example, see Ackoff *et al.*, *Designing a National Scientific and Technological Communication System*; J. Senders, "The Scientific Journal of the Future," *The American Sociologist*, Vol. 11 (1976), pp. 160–64; Lancaster, *Toward Paperless Information Systems*; Hiltz and Turoff, *Network Nation*; King *et al.*, *Scientific Journals in the United States*; and I. L. Horowitz, *Communicating Ideas: The Crisis of Publishing in a Post-Industrial Society* (New York: Oxford, 1986).
36. King *et al.*, *Scientific Journals in the United States*, p. 309.
37. B. A. Davis, "Electronic Manuscript Preparation and Markup," *Bulletin of the American Society for Information Science*, Vol. 13, no. 2 (December/January 1987), pp. 33–34; Association of American Publishers, *Electronic Manuscript Project: Standard for Electronic Manuscript Preparation and Markup* (Washington, DC: AAP, 1987); and University of Chicago Press, *Chicago Guide to Preparing Electronic Manuscripts* (Chicago, IL: Author, 1987).
38. Hiltz and Turoff, *Network Nation*.
39. "UMI's General Periodicals Ondisc Now Available," *Information Today* (November 1990), p. 24.
40. US Congress, Office of Technology Assessment, *Informing the Nation: Federal Information Dissemination in an Electronic Age*, OTA-CIT-396 (Washington, DC: US Government Printing Office, 1988), p. 62.
41. National Library of Medicine, *Preservation of the Biomedical Literature: A Plan for the National Library of Medicine* (Bethesda, MD: Author, 1985); National Library of Medicine, *Programs and Services, Fiscal Year 1988* (Bethesda, MD: Author, 1988); and M. M. Byrnes, "Preservation of the

Biomedical Literature: An Overview," *Bulletin of the Medical Library Association*, Vol. 77, no. 3 (July 1989), pp. 269–275.

42. Advances in optical character recognition (OCR) technology are making it increasingly possible to translate faxed images into character-coded text, although the capabilities are limited at present.
43. Retrieval systems with "hypertext" capabilities enable users to skip from an article citation or abstract to a linked database containing the full text of an article. Users can also jump from one full-text database to another. K. Nesbit and E. G. Miner, "BRS/Links to the Future: Online Hypertext is Born," *Online* (May 1990), pp. 34–36; and J. Nielsen, *Hypertext and Hypermedia* (Boston: Academic Press, 1990).
44. T. B. Hickey and A. M. Calabrese, "Electronic Document Delivery: OCLC's Prototype System," *Library Hi Tech*, Vol. 4, no. 1 (Spring 1986), pp. 65–71; A. M. Calabrese, "The Electronic Journal: A Review of Trends and Their Implications for Scholarly Communication," Paper presented at the annual meeting of the Central States Communication Association, Cincinnati, OH, April 1986, ERIC, ED 278 076; and A. M. Calabrese and S. R. Acker, "Information System Design: A Case Study in the Generation of Innovations," Paper presented at the annual meeting of the International Communication Association, Montreal, Canada, May 1987, ERIC, ED 295 222.
45. J. A. Hearty and V. K. Rohrbaugh, "Current State of Full Text Primary Information Online with Recommendations for the Future," *Online Review*, Vol. 13, no. 2 (April 1989), pp. 135–140.
46. An accurate count of the constantly growing number of full-text databases is difficult to provide, although the semi-annual Fulltext Sources Online and the annual Directory of Periodicals Online provide updated lists of over a thousand online full-text publications. The number of online utilities or "host systems" carrying full-text databases (including serials) is also growing and now includes BITNET, DIALOG, BRS, NLM, STN, ORBIT, LEXIS, and NEXIS. For further information on how to locate various electronic journals see C. W. Bailey, "Electronic (Online) Publishing in Action: The Public-Access Computer Systems Review and Other Electronic Serials," *Online* (January 1991), pp. 28–35; D. P. Gillikin, "Document Delivery from Full-Text Online Files: A Pilot Project," *Online* (May 1990), pp. 27–32; and D. L. McMaster, "Dialog Journal Name Finder: Online Journal Coverage Made Easier," *Online* (July 1991), pp. 24–27.
47. N. Mark, "Electronic Document Delivery and Electronic Publishing: Experiments Supported by the Commission of the European Communities," *Libri*, Vol. 39, no. 2 (June 1989), pp. 165–69.
48. R. M. Campbell and B. T. Stern, "ADONIS: A New Approach to Document Delivery," *Microcomputers for Information Management*, Vol. 4, no. 2 (June 1987), pp. 87–107; and D. Manodarshani and G. Martin, "The ADONIS Experiment," *Health Libraries Review*, Vol. 6, no. 4 (December 1989), pp. 193–99.
49. US Congress, Office of Technology Assessment, *Informing the Nation.*
50. M. L. Dertouzos and J. Moses (eds.), *The Computer Age: A Twenty-Year View* (Cambridge, MA: MIT Press, 1981).
51. B. M. Compaine, *Understanding the New Media: Trends and Issues in Electronic Distribution of Information* (Cambridge, MA: Ballinger, 1984), p. 79.
52. Nesbit and Miner, "BRS/Links to the Future;" and Nielsen, *Hypertext and Hypermedia.*
53. Society for Scholarly Publishing, *Special Report: Optical and Videodisc Technology* (Washington, DC: Author, 1985).
54. Senders, "The Scientific Journal of the Future."
55. Compaine, *Understanding the New Media.* See also P. Battin, "The Library: Centre of the Restructured University," *Scholarly Publishing,* Vol. 17, no. 3 (April 1986), pp. 255–67.
56. Bailey, "Electronic (Online) Publishing in Action."
57. C. Suplee, "Fusion Confusion," *Washington Post* (April 30, 1989), p. C1; and D. E. Chubin, *Peerless Science: Peer Review and U.S. Science Policy* (Albany, NY: State University of New York, 1990).
58. Price, *Little Science*, Big Science.