Scientific Communication: New Roles and New Players

Julie M. Hurd

SUMMARY. Communication in science has evolved from a process dependent on print-on-paper to one increasingly reliant on electronic media as databases have replaced indexes and journals have shifted to electronic formats. This migration from print to electronic has transformed the roles of virtually all participants in the system of scientific communication. Scientist-authors, publishers, and librarians have all assumed new duties as the Internet and the World Wide Web have blurred boundaries and realigned responsibilities.

This paper examines some of these changes in detail with reference to a communication model developed during a print-based time by sociologists William Garvey and Belver Griffith. An updated model of the current scientific communication system will be presented that incorporates developments that have changed the very nature of research and publishing and have altered, as well, the ways that libraries and librarians interact with scientists and publishers. The challenges associated with these changes are identified and discussed. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <http://www.HaworthPress.com> © 2004 by The Haworth Press, Inc. All rights reserved.]*

Julie M. Hurd, PhD (Chemistry), MA (Library Science), is Science Librarian and Coordinator for Digital Library Planning, University of Illinois at Chicago, P.O. Box 8198, M/C 234, Chicago, IL 60680 (E-mail: jhurd@uic.edu).

[Haworth co-indexing entry note]: "Scientific Communication: New Roles and New Players." Hurd, Julie M. Co-published simultaneously in *Science & Technology Libraries* (The Haworth Information Press, an imprint of The Haworth Press, Inc.) Vol. 25, No. 1/2, 2004, pp. 5-22; and: *Emerging Issues in the Electronic Environment: Challenges for Librarians and Researchers in the Sciences* (ed: Jeannie P. Miller) The Haworth Information Press, an imprint of The Haworth Press, Inc., 2004, pp. 5-22. Single or multiple copies of this article are available for a fee from The Haworth Document Delivery Service [1-800-HAWORTH, 9:00 a.m. - 5:00 p.m. (EST). E-mail address: docdelivery@haworthpress.com].

http://www.haworthpress.com/web/STL

Digital Object Identifier: 10.1300/J122v25n01_02

KEYWORDS. Communication in science, electronic publishing, scholarly publication

INTRODUCTION

Scientific communication is a complex and interrelated system that has evolved over several centuries. Its origins lie in the first scientific journals that developed in the late seventeenth century from the correspondence of scientific societies comprised of individuals with broad and general interests in scientific discovery. The earliest scientific journals reflected the wide-ranging interests of early society members, but gradually discipline-specific societies were formed, and these associations began to publish their own more specialized journals. As the number of journals increased, indexes and abstracts were created to provide access to the contents of the ever-growing scientific literature; new publishers emerged that specialized in these secondary publications. By the middle of the twentieth century, scientific publishers included both society and for-profit organizations. The latter often produced the most narrowly-specialized titles.

Publishers of scientific journals depend on scientist-authors to provide content for their volumes, and the peer-review process has evolved as a mechanism to validate the quality of the science that is published. The authors of scientific journal articles, in turn, have traditionally relied on the stature of journals in which they publish their research to advance their careers; this is especially the case for those scientists employed in research universities. Initially, scientists were able to purchase all of the publications needed to support their research, but, as the literature grew, they became increasingly dependent on libraries to provide them with needed information, whether primary research journals or secondary service publications. The growth of research libraries during the twentieth century paralleled the growth of both profit-sector and society publishers and resulted in an economic interdependence that continues to the present.

Scientific communication links these very diverse individuals and organizations by the common thread of their shared interests in the outcomes of scientific research. Since the appearance of the first scientific journals in the late seventeenth century, the roles of individuals and organizations within the communication system have been reasonably well understood. This situation shifted dramatically with the emergence

of several powerful change agents during the latter part of the twentieth century.

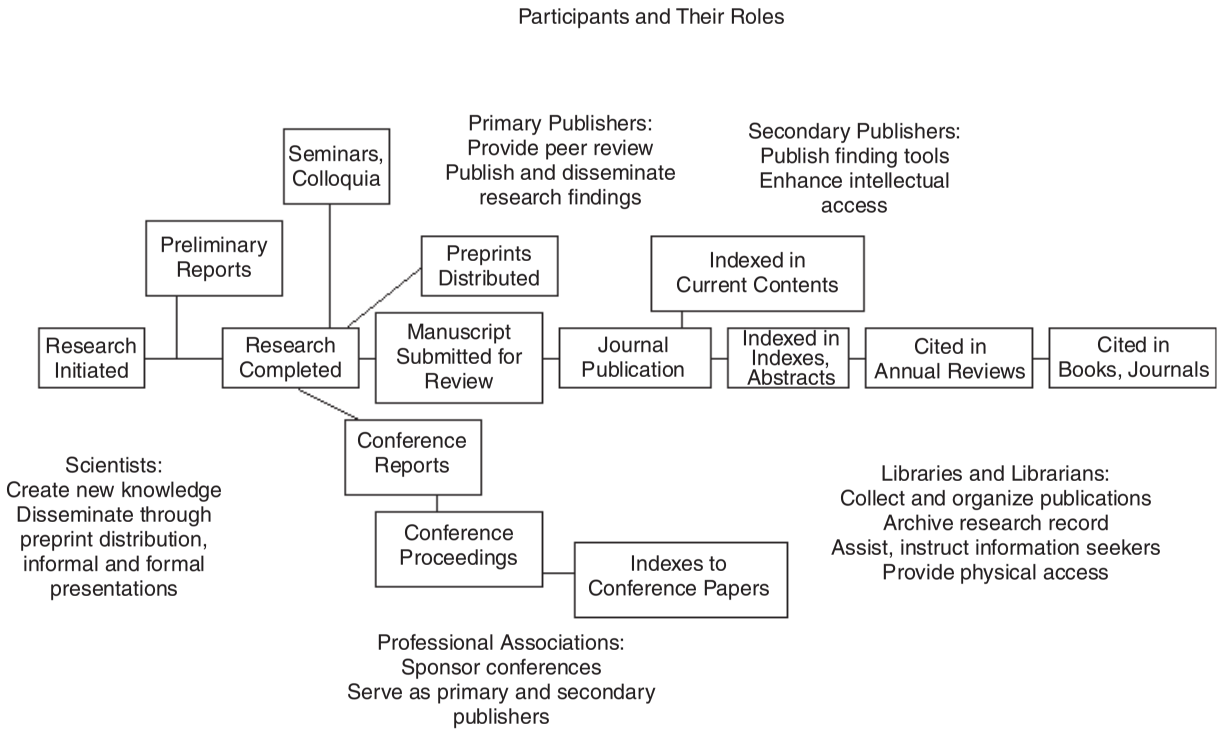
The first catalyst for change was the computer, although its ultimate power to destabilize the communication system wasn't realized initially by most participants. The earliest applications of computers by the publishing industry increased efficiencies in the production process for print materials; for example, computer-driven typesetting reduced the delay in bringing print journals to publication. As secondary publishers adapted computer technology to streamline and speed the publication of print indexes and abstracts, they created bibliographic databases, initially as by-products, that quickly became the preferred mode of searching the scientific literature. Still later, electronic journals would hasten the transformation from a print-based to an electronic system.

The two other major catalysts for change were the Internet and the World Wide Web. The Internet and the Web were both products of scientists seeking to find better ways to facilitate sharing of research results; both developments have had a much broader and disruptive impact on the entire system of scientific communication. This paper focuses on the changing system of scientific communication outlined briefly in the preceding paragraphs and explores how those changes have resulted in new roles for participants and have brought new stake-holders into the system.

COMMUNICATION IN THE PRINT ERA

Sociologists of science William Garvey, Belver Griffith, and co-workers developed a model of a scientific communication system based on their observations of psychologists (Garvey and Griffith 1972; Garvey 1979, and references cited therein). Garvey and Griffith approached the study of scientific communication as a social process, and their investigations produced a model of the communication system in psychology from the initiation of a research project to its ultimate assimilation into the discipline's knowledge base. The Garvey/Griffith model was subsequently demonstrated to be generally applicable across many other disciplines in the physical, life, and social sciences. Figure 1 depicts the Garvey/Griffith model as it was outlined over thirty years ago. The various steps in the creation and dissemination of new knowledge are shown as a timeline. The participants at each stage and their roles in the system are indicated.

FIGURE 1. Scientific Communication Traditional Garvey/Griffith Model



The Garvey/Griffith model depicts both formal and informal communication among individuals and groups. It is essentially a sequential process with the central activity publication of research in peer-reviewed scientific journals. After journal publication, other aspects of the model represent the incorporation of the scientist's findings into the discipline's literature through inclusion in indexes, abstracts, annual reviews, and other publications. At each stage, the roles of both individuals and organizations were clearly understood by all system participants; there was little ambiguity in either the sequence or the appropriate actions. For example, a scientist/author knew without question that a manuscript would be submitted to a peer-reviewed scientific journal appropriate for its content. In many scientific specialties, the preferred venue for publication was a journal published by the scientific association in that field: for example, *JAMA* (*The Journal of the American Medical Association*) or the American Chemical Society's *Journal of Organic Chemistry*.

As scientific research became increasingly specialized, for-profit publishers saw opportunities to serve the emerging sub-disciplines and began to publish titles that were intended for a very narrow and focused readership. Both scientific societies and the commercial scientific publishers that emerged mid-twentieth century co-existed and shared the same market for their products, a mix of individual scientists and research libraries. Libraries and librarians occupied a well-established place in the system as well. Libraries acquired and maintained the growing collections of scholarly journals, indexes and abstracts, annual reviews, and textbooks and were committed to archiving knowledge in perpetuity for society. Librarians understood the structure of the literature, built the research collections, and helped scientists locate the materials needed to support their research. Even as Garvey and Griffith were developing their model, however, agents for change were appearing that would eventually prove disruptive to the entire communication system.

TECHNOLOGICAL CHANGE AGENTS

Computers in the Workplace

During the decade following World War II, high-speed computing became generally available to the scientific and business communities. Applications in the research sector were focused on manipulation and

analysis of large bodies of data generated in experiments or on theoretical calculations that involved complex numerical and mathematical methods. In the business sector, processes such as inventory control and accounting made use of the new technology. In both scientific research and business, initial applications of computers supported doing long-established activities more accurately and more efficiently, but they did not yet disrupt the familiar routines.

The launch of the Russian space satellite Sputnik in October 1957 surprised the Western world and served to catalyze more wide-ranging societal changes. In the United States, Congress began to pay more attention to scientific developments, and the funding climate improved for agencies supporting research such as the National Science Foundation (NSF). During the decade of the 1960s, a number of major government grants were awarded to scientific publishers to support efforts to speed and improve the communication of research findings. Awards to publishers of indexes and abstracts led to the creation of the first large bibliographic databases such as *Psychological Abstracts*, *MEDLINE*, and *Chemical Abstracts*. Simultaneously, journal publishers were beginning to adopt computer-assisted typesetting thereby creating content in machine-readable format. These initiatives represent the beginnings of the shift from a paper-based communication system to one that is computer-based. With this shift, traditional roles for communication system participants began to change.

New Competencies

In the publishing industry, new skill sets were required to incorporate technology into manual processes that had developed and evolved post Gutenberg. Editors began to work with content viewed on computer screens, and manual typesetting was replaced by computer-driven equipment. The heads of publishing houses needed to understand the larger issues so that they could position their companies strategically within a rapidly changing environment. Whether the question of the moment related to purchase of equipment or to the design of new business models, the old ways of doing business were no longer enough to ensure future successes. At all levels in the organization, the impact of computers both challenged and enriched the workplace experience.

The scientists whose research is central to the communication system also found their activities altered by technology. Many began to employ computers in their research, both in the laboratory and in the preparation of manuscripts to be submitted for publication. Some became more di-

rectly involved in manuscript preparation as personal secretaries gave way in many organizations to smaller staffs of "word-processors." With the appearance of desktop computers during the decade of the 1980s, the stage was set for authors to move even closer to assuming duties previously associated with the publishing sector.

Librarians also were expected to acquire new competencies related to technology. Libraries had been among the "early adopters" of computers in support of their processing and collection control functions, parallel to the adoption of computers by corporations. While technical services staff were the first in libraries to use technology, public services staff quickly became involved as bibliographic databases moved from being exploratory projects in information science research to production products for the library marketplace.

During the decade of the 1970s, the information industry emerged as profit-sector companies such as System Development Corporation, Dialog Information Services, and Bibliographic Retrieval Services were established to broker new products by assembling collections of databases that were licensed by their publishers, and developing search engines to support retrieval of the information they contained. While some of these search services were used by researchers themselves, most were designed for use by information specialists such as public services librarians. Reference librarians, particularly those in science and technology settings in industry, government agencies, and universities, eagerly acquired the skills to search online databases for their patrons. Along the way, many of them also developed technological expertise that opened doors to careers in the developing information industry whether in marketing, consulting, customer service, or product development.

THE INTERNET AND THE WORLD WIDE WEB

The most recent, and possibly the most powerful, change agents for scientific communication have been the Internet and the World Wide Web. The Internet was born in a telecommunication network supported by the U.S. government that was designed to facilitate communication among research scientists. Barry Leiner, with others who helped to develop the Internet, capture this in *A Brief History of the Internet* where they state, "The Internet is at once a world-wide broadcasting capability, a mechanism for information dissemination, and a medium for collaboration and interaction between individuals and their computers without

regard for geographic location" (Leiner et al. 2000). They identify four distinct aspects in the origins of the Internet: the technological innovations that permitted open architecture networking, the operations and management contributions to the infrastructure, the social changes that built on e-mail to radically alter communication behavior, and the commercialization that supported the evolution of research results into a broadly used and widely available resource.

The World Wide Web, developed by Tim Berners-Lee and others in the high energy physics community, provided a user-friendly and intuitive interface to link, search, and display Internet-based resources (Internet Pioneers n.d.). Using the Web requires very little understanding of the complexity of the underlying technology; the Web browsers that now exist allow users ranging from children in grade school to research scientists to share information globally on their desktop computers. The ease of use of the Web has encouraged numerous commercial applications including those in electronic publishing, a development that has transformed scientific communication and is the subject of this article.

SCIENTIFIC COMMUNICATION IN AN ELECTRONIC ENVIRONMENT

Initial predictions of a transformed system of scientific communication were sometimes simplistic and overestimated the rate of change with respect to adoption of innovations. Some visionaries predicted a future that discounted discipline-specific factors that now have been realized as significant. For example, the success of e-print archives in high energy physics suggested a communication model that was based on e-print databases and would eventually replace scientific journals. While a few specializations enthusiastically adopted e-print archives, the vast majority of others did not.

Kling and McKim (2000) provided a thoughtful analysis that takes into account disciplinary differences in communication behavior. Their approach captures the complexities of scholarship and supports a better understanding of what the future might bring. Crawford, Hurd, and Weller (1996) and Hurd (2000) also proposed new models of scientific communication that incorporate discipline-specific attributes.

At this time, electronic journals published on the World Wide Web are the norm in most scientific disciplines. While the demise of the scientific journal was predicted, in fact, that has not yet come to be. Rather, those formerly-print publications are now also published electronically

in a format that retains the strengths of print, such as peer-review, but offers new and powerful functionalities such as reference linking. Both scholarly society and for-profit publishers of print journals quickly realized the need to digitize their journals; most of them now offer both print and electronic versions of titles. The business models necessary to support parallel formats have been more difficult to develop, with resulting stresses on both publishers and their library and individual markets.

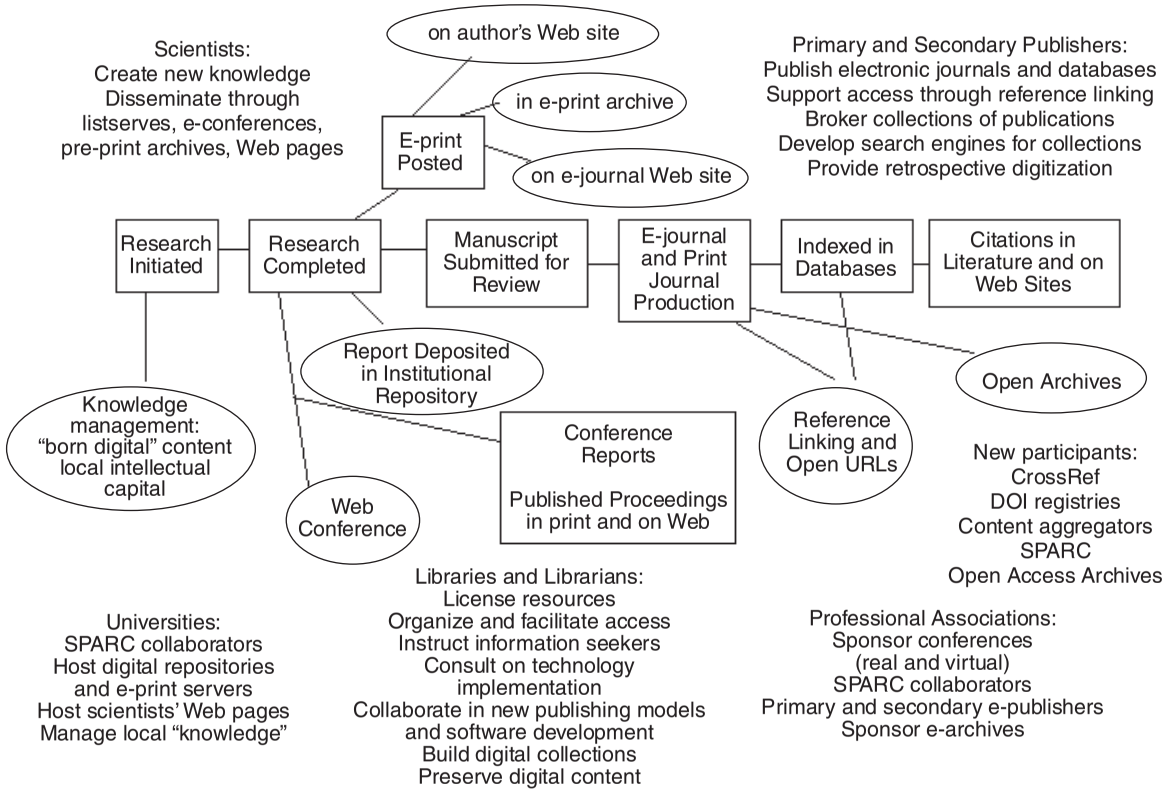
CHANGING ROLES AND NEW RESPONSIBILITIES

Even as publishers are caught up in the ongoing transformation from print to electronic so are all other participants in the system. What was once a linear process with clearly defined roles has evolved into a more complex and interrelated environment. In this dynamic period, traditional roles have blurred and new roles have emerged, sometimes assumed by familiar players, but other times by new entities. Figure 2 depicts some of this complexity and highlights changes in the process of scientific communication. The rectangular elements in the figure represent enduring activities and functionalities, some of which now incorporate technology. For example, those fields that had a culture of disseminating preprints, have adapted and now utilize e-print archives. Other features of this model, those shown as ovals, were not part of the print-based system and identify new functionalities and new participants.

New collaborations are emerging as a result of changes that potentially involve all participants in the system. Kate Wittenberg, director of an electronic publishing initiative at Columbia University, described some of these from a scholarly publishers' perspective (Wittenberg 2003). She asserted that the changes in scholarly communication were blurring roles and responsibilities for editors and authors, even as technology presented creative opportunities for everyone involved in organizing and presenting new knowledge to readers. She challenged publishers to create an organizational model that fosters collaborations among authors, editors, book designers, technologists, and marketing staff and that builds in formal mechanisms for involvement of scholars, librarians, and educators as well.

The Association of Research Libraries sponsored a forum in October 2001 that examined how "the changes in the environment of scholarly communication were shifting or blurring boundaries of responsibilities within the library, and externally among the many stakeholders in the system" (ARL 2002). The report of papers and discussions from that

FIGURE 2. Scientific Communication in a Digital World



meeting is a succinct overview of the opportunities and challenges for libraries; the references found in that report link to additional details on many of the issues explored in this paper. Some of the changing roles identified for research libraries include:

- shifting emphasis from building print collections to licensing electronic resources
- participating in initiatives such as SPARC (the Scholarly Publishing and Academic Resources Coalition) that seek to develop affordable publishing alternatives
- digitizing materials and building locally maintained but widely shared digital collections
- collaborating with other units in the organization, or outside, to create virtual collections from dispersed resources
- developing new services, many of them technology-based, to enhance access within the organization and across institutional boundaries.

Brach (2001) and Hurd and Weller (2004) provide analyses of the successes and remaining problems that electronic resources pose for managers of research library collections.

Acquisition of Electronic Resources

The growing emphasis on electronic resources is especially important in science, technology, and medicine (STM). These disciplines were the leaders in electronic publishing, and STM resources are among the most highly developed and costly. Electronic resources require fundamentally different approaches to acquisition than print materials. Library selectors now find themselves going beyond the assessment of content that informed print selection; it is also essential to evaluate the functionality of a user interface and know the hardware and software requirements before deciding to license a resource.

The licenses themselves continue to be one of the more demanding aspects of the evaluation process and frequently require the intervention of the parent organization's legal counsel in order to determine compatibility with the parent organization's policies. It is not unusual to find clauses in a license that are unacceptable and subject to further negotiation and adjustment before signing. Large complex organizations may have facilities in multiple locations; for example, universities with more than one campus or corporations with facilities at multiple sites. In ei-

ther case, the definition of "site" in a license can be a critical issue. Another area of concern in licenses is restriction on interlibrary lending. Many publishers of e-journals do not permit these items to be used to supply interlibrary loan requests. Other restrictive terms may exist that hinder use in electronic reserve operations or distance education.

Some providers license products for a set number of simultaneous users, for example, *SciFinder Scholar* and the *Web of Knowledge*. This type of resource requires a library to know enough about its user community to make a wise decision about anticipated use. The price of the resource will depend on the maximum number of users supported. If a library makes a "best guess" as to how many "seats" to license, timely use statistics and a flexible agreement with the provider can allow for later adjustment to reflect actual use. At the same time, this type of access may be unfamiliar to users who are turned away and will not necessarily realize the reason. The user interface may not provide a message understandable by users, so this situation represents an area where librarians must educate their constituencies.

As publishers and aggregators increased their e-journal offerings, many began to broker bundled collections that included either their entire product line or discipline-specific groupings. These prepackaged assemblages typically include many titles for which a library lacks a current print equivalent. Kenneth Frazier comments on the disruptive effect of this marketing strategy, which he calls the "big deal," on the library acquisition process (Frazier 2001). He points out that these group licenses typically include constraints on cancellation of the e-journal titles that are included. Bundled titles may dilute a library's collection with titles for which it has no need. The "big deal" favors the larger publishers and may leave a library with insufficient resources to select from the offerings of smaller publishers whose journals may contribute uniquely to a discipline. While patrons may perceive only the short-term gain–the addition of many more e-journals–in the long term, the collection may weaken and lose its special strengths that differentiate it from the collections of other institutions.

The Scholarly Publishing and Academic Resources Coalition (SPARC)

In response to some of these financial pressures, libraries have partnered with small scholarly publishers and presses to develop alternative journals that promise cost savings through SPARC, an initiative of the Association of Research Libraries (http://www.arl.org/sparc/).

SPARC-sponsored STM titles have succeeded in attracting scientists, both as members of their editorial boards and as authors, and include some very remarkable successes such as *Organic Letters*, a collaboration with the American Chemical Society. *Organic Letters*, now in it its fifth year of publication, has the highest impact factor of all journals publishing more than 100 articles per year in organic chemistry for the second year in a row according to the 2002 ISI *Journal Citation Reports* (ACS 2003). Collaborations such as SPARC offer an opportunity for librarians to be active participants in the scholarly publishing process and to shape the future of scientific communication.

Reference Linking

The migration to electronic publishing of journals and databases has made feasible functionalities not possible in a print environment. Reference linking, sometimes known as citation linking, is considered by Priscilla Caplan to be "one of the most important added values to emerge from the rise of electronic scholarly publishing" (Caplan 2001). She defines reference linking "as the ability to go directly from a citation to the work cited, or to additional information about the cited work." Sources of citations include entries in databases, references in a full-text article, or any other clickable link. The targets of these links are generally the articles in libraries' licensed e-journals, but may also include materials on patent office or other government agency Web sites as well as commercial and personal Web pages. In the best of worlds, all this linking would be seamless, activated only by a single mouse click; in the present reality, matters are not yet quite that simple. How reference linking is enabled varies significantly at this time and is not fully realized, but its promise has resulted in new alliances among publishers and other information organizations.

CrossRef, DOIs, SFX, and Open URLs

CrossRef is an initiative directed toward resolving some of the barriers to seamless reference linking. CrossRef (http://www.crossref.org) is a joint effort by major primary and secondary publishers to provide an infrastructure for reference linking through use of the Digital Object Identifier (DOI) (Mader 2001). DOIs are unique identifiers for digital objects such as article text and, possibly, even discrete portions of articles such as figures or tables. DOIs are persistent and are registered by the publisher with the URL where the article resides in a database main-

tained by the International DOI Foundation. The DOI must be searched in this database to determine the URL, a process referred to as "resolving." CrossRef-participating publishers deposit article bibliographic metadata and DOIs into a database maintained by CrossRef. When a user clicks on a reference that offers a CrossRef-enabled link to full text, the CrossRef switching system "resolves" the DOI by translating it into the correct URL and connects the user to the article on the publisher Web site where the user would be authenticated as a valid subscriber to the journal. The CrossRef database also can be queried by participating publishers to create "actionable" links in lists of references. At this time, CrossRef cannot address the context of the user, i.e., the organizational environment that determines access privileges. CrossRef cannot direct that individual to sources other than the primary publisher. For example, libraries may use aggregators to authenticate users before passing them off to a publisher site, or they may channel users coming from outside the organization's computing network to a proxy server for authentication.

Context-sensitive reference linking tools support the need of many libraries to localize their linking functions by referring their users to the "appropriate copy" of an article, i.e., the copy that has been licensed for that institution's users whether that be from a publisher, an aggregator, or through a consortium. Libraries frequently have more than one choice of provider for a particular resource. The library may also wish to direct users to its print collections for items not available electronically or to document delivery services for items not held locally.

The seamless interconnectivity that is the dream of all users is not necessarily easy for libraries to implement. The first efforts to resolve the "appropriate copy" problem were labor-intensive and often required a library to convey information to a database provider on the source for each and every journal indexed in a database to which the library wished to provide reference linking. Of course, when a library adds or cancels titles or switches providers, holdings information must be updated. For very large libraries, the initial customization can require considerable time up front, with lesser amounts of time required to maintain current holdings information. And this sort of activity would need to be replicated, with variations, in every other database that supports local customization in this fashion. Clearly, this does not scale well in times of tight staffing! The need for scalability has driven the development of products designed to facilitate, at the local library level, the integration of resources acquired from an array of providers.

SFX (for Special Effects) is a proprietary, context-sensitive reference linking product commercially available from Ex Libris, a provider of library integrated systems (http://www.exlibrisgroup.com/sfx.htm). The software makes use of OpenURL, an open source protocol and proposed standard that provides a syntax for the address and other descriptive elements such as the DOI and metadata that identify a specific digital object, e.g., an article in a full-text e-journal. The SFX server, knowing the requester's affiliation, can identify the resources available to that user and determine the location of an appropriate copy/copies. Only the SFX server needs to store the list of preferred providers, and staff do not then need to customize products individually, provided the resources are SFX-aware.

To provide the apparently seamless linking among resources so desired by librarians and users requires the interaction of all the components described above. DOIs must be in place to provide persistent identifiers, and the OpenURL protocol employed to standardize metadata elements essential to locating content. The CrossRef database serves as a reference for DOIs and citation metadata, and SFX (or a similar product) provides resolution and referral at the local library level. Implementing reference linking is a truly collaborative process that involves numerous participants; it has resulted in new responsibilities for primary and secondary publishers and librarians, and generated new organizations to maintain the necessary data.

Building Digital Collections

Linking licensed resources has enhanced access to the published record represented by scientific journals, patents, and government documents. Other initiatives underway are focusing on materials that may be unique to one institution or rare and special in some other way. Many libraries now are pursuing strategies to enhance access to their special collections, whether text, image, or other media. Collaborating with faculty, academic departments, local organizations such as museums, and not-for-profit agencies, librarians are building digital collections that make locally-held or dispersed resources more easily identifiable, searchable, and accessible. The digital repositories that are under development are wide-ranging in content. Some, such as MIT's DSpace, manage local intellectual capital by bringing together university research in digital form, including preprints, technical reports, working papers, conference papers, images, and more (https://dspace.mit.edu/index.jsp).

Other digital repositories are being created from rich and valuable retrospective collections that formerly required scholars to visit the library holding the resources. Many special collections departments have eagerly begun to digitize their holdings thereby making them widely available and supporting their preservation. Librarians participating in digitization projects have acquired new skills related to technology, but have also drawn on their traditional strengths in organizing information and providing instruction to potential users. New infrastructures such as the Open Archives Initiative have emerged to link digital collections by harvesting the metadata that libraries create to describe their digital collections (http://www.openarchives.org/). New standards are being written, and the software is under development to support interoperability and digital rights management. The collaborations that are forming will change how research is done and will make primary sources available to an increasingly diverse audience.

New Services to Users

Technology has made the developments above possible and, in so doing, challenged existing approaches to the provision of library services. As ever more information is available electronically, the concept of place-based services and resources is eroded. If many of a library's users do not need to come into the building to obtain the information they need, then new delivery mechanisms are required. Web-based instruction, possibly integrated with course management software such as BlackBoard, has the potential to reach students who might be in campus residence halls, but could instead be enrolled in distance education programs far from any library. Librarians are partnering with faculty and instructional technology staff to create and develop the tools needed to use digitized resources. Virtual or chat reference represents another approach to reaching off-site users and, in many cases, supports outreach to previously unserved groups. Virtual reference is frequently collaborative, as it may involve referring questions to other libraries to take advantage of special expertise or different time zones to insure around-the-clock services.

FUTURE DIRECTIONS

Scientific communication systems will continue to evolve as the developments outlined above give rise to new approaches to sharing the

results of research. We are in the midst of a transformation that has created new roles for authors, publishers, information technologists, and librarians. Technology has been the catalyst and will continue to ensure a fluid environment, with change the only constant. Behavioral determinants will also shape the future as both traditional players and new participants interact to achieve common goals. Organizational cultures are challenged to respond to new participants and increased collaborations. Economic pressures, barely alluded to in this article, will also influence the outcomes. In the words of Jay Jordan, President and Chief Executive Officer of OCLC, "We face some exciting prospects in this new environment of digital collections. . . . Working together, we can help change how people conduct research, scholarship and education, and these changes will have far-reaching benefits for humanity in the years to come" (Jordan 2003).

REFERENCES

American Chemical Society. http://pubs.acs.org/journals/orlef7/ (accessed July 20, 2004).

Association of Research Libraries. 2002. Collections and access for the 21st-century scholar: Changing roles of research libraries. *ARL: A Bimonthly Report on Research Library Issues and Actions from ARL, CNI, and SPARC.* Washington, DC: ARL. no, 225, December 2002.

Brach, Carol. 2001. Electronic collections–Evolution of strategies: Past, present, and future. *Science & Technology Libraries* 21(1/2):17-27.

Caplan, Priscilla. 2001. Reference linking for journal articles: Promise, progress, and perils. *portal: Libraries and the academy* 1(3):351-356.

Crawford, Susan Y., Hurd, Julie M. and Weller, Ann C. 1996. *From print to electronic: The transformation of scientific communication.* ASIS Monograph Series. Medford, NJ: Information Today.

Frazier, Kenneth. 2001. The librarian's dilemma: Contemplating the costs of the "big deal." *D-Lib Magazine*, 7. http://www.dlib.org/dlib/march01/frazier/03frazier.html (accessed July 20, 2004).

Garvey, William D. 1979. *Communication: The essence of science.* Elmsford, NY: Pergamon Press.

Garvey, William D. and Griffith, Belver C. 1972. Communication and information processing within scientific disciplines: Empirical findings for psychology. *Information Storage and Retrieval* 8:123-126.

Hurd, Julie M. 2000. The transformation of scientific communication: A model for 2020, *Journal of the American Society for Information Science* 51(14):1279-1283.

Hurd, Julie M. and Weller, Ann C. 2004. Evolving electronic journals: Accomplishments and challenges. *Journal of Electronic Resources in Medical Libraries* 1(1):31-49.

Internet Pioneers: Tim Berners-Lee. n.d. http://www.ibiblio.org/pioneers/lee.html (accessed July 20, 2004).

Jordan, Jay. 2003. Digital collections, e-learning and libraries. *OCLC Newsletter*, no. 261:2-3.

Kling, R. and McKim, G. W. 2000. Not just a matter of time: Field differences and the shaping of electronic media in supporting scientific communication. *Journal of the American Society for Information Science* 51(14):1306-1320.

Leiner, Barry M., Cerf, Vinton G., Clark, David D., Kahn, Robert E., Kleinrock, Leonard, Lynch, Daniel C., Postel, Jon, Roberts, Larry G., and Wolff, Stephen. 2000. A brief history of the Internet. The Internet Society http://www.isoc.org/internet/history/brief.shtml (accessed July 20, 2004).

Mader, Cynthia. 2001. Current implementation of the DOI in STM publication. *Science & Technology Libraries* 21(1/2): 97-118.

Wittenberg, Kate. 2003. Scholarly editing in the digital age. *The Chronicle of Higher Education* 49(41):B12.