This article examines the ways in which information technology developments have changed the academic library over the last few decades, and speculates about further changes to come. In an effort to expose the major themes, I have glossed over many important details, and I hope that those knowledgeable about these details will forgive any hints of revisionist history. Things are never as simple or tidy as this kind of brief overview implies.

Richard West and Peter Lyman have suggested a three-phase procession of the effects of information technology on organizations: modernization (doing what you are already doing, though more efficiently); innovation (experimenting with new capabilities that the technology makes possible); and transformation (fundamentally altering the nature of the organization through these capabilities). This is a very helpful way of understanding what has happened to academic libraries in the latter part of the twentieth century, but one needs to recognize that libraries function within a much broader context that includes the publishing and information marketplace, changing modalities of scholarly communication, and evolving capabilities in the user community. As other articles in this issue illustrate, information technology has profoundly changed all aspects of higher education and scholarship, and these changes continue to unfold today. Innovation and transformation for academic libraries take place within this broader context; libraries cannot be considered in isolation from this context.

The first part of the story is dominated by the theme of automation (modernization): libraries applied a growing range of information technologies to the management of collections of primarily print information. This was a supremely
The Second Automation

Age: The Rise of Public Access

By the 1980s, the shared cataloging systems had already become quite as large as a result of retroactive conversion programs for older books and some years of use in cataloging new acquisitions. The central library would create a cataloging entry for a book and prepare cards for its card catalog. The cataloger would then push a button on a terminal, and the cards would be loaded into the system. If the book was already cataloged, the cataloger would consult the card held and could not actually view the works on screen.) In addition, consortia developed union catalogs that merged materials from multiple libraries, promoting more efficient growth of the major order catalog; a group of libraries that wanted to work together could create a “virtual” combined collection. As the Internet began to grow, library catalogs were connected to the Net so that they could be consulted simultaneously by people anywhere in the world. Particularly for those scholars in the humanities, the availability of online catalogs and electronic mail ushered in a new era of access and communication.

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particularly expensive and were open mostly to researchers in industry. Although a faculty member at an academic institution might be offered a few meditated searches a year, the notion of offering searches on a wide scale to students was economically unthinkable. Not until the late 1980s and early 1990s were these abstracting and indexing services marketed to the library community, but not already in the database, the library would create a cataloging record, which other libraries could then use. Shared cataloging was pioneered by a number of library consortia in the 1960s and 1970s. Today, these efforts have consolidated into two major shared cataloging systems, one operated by OCLC in Columbus, Ohio, and the other by the Research Libraries Information Network in Palo Alto, California.

The First Automation Age: Computerizing Library Operations

There is a rich and fascinating early history of information technology in libraries, reaching back to the 1950s and early 1960s, as part of the post-Sputnik revolution in science and technology. Many of the changes simply made existing manual systems more efficient and helped to control their costs. This was a period of significant tradeoffs in the introduction of technology to automate library operations. Several companies offering computer-based ordering systems were offered large, centralized databases by people other than members of the local academic community. They also saved physically present in the library facilities.* As often stated by the typical library user.

It is easy—from this distance in time—to underestimate the extent of change that is occurring in the 1980s. They made library materials more accessible and easier to use. They lowered the barriers to entry in entirely new ways. They made the idea of “anytime, anywhere” remote access to library resources real and common everyday practice. They made libraries move beyond the online bibliographic services to the actual books. The substantial growth of these databases has been particularly useful to those who use them to determine the role that libraries played in introducing many people on campuses in the 1960s to electronic mail, which was marketed to the library community, but not already in the database, the library would create a cataloging record, which other libraries could then use. Shared cataloging was pioneered by a number of library consortia in the 1960s and 1970s. Today, these efforts have consolidated into two major shared cataloging systems, one operated by OCLC in Columbus, Ohio, and the other by the Research Libraries Information Network in Palo Alto, California.

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more complex. International information sharing and collaboration were greatly facilitated.

The use of the Net became critical in many forms of scholarly communication. Preprints and technical reports became widely distributed on the Net, democratizing access to this information and speeding up the rate of communication. Monographs and reference works morphed into databases and scholarly Web sites. Government databases and datasets became critical resources in the physical and life sciences, and even some areas of the humanities. Access to geospatial and remote-sensing data transformed the earth sciences.

Community databases became essential parts of the scientific discourse in areas such as molecular biology and genetics. Scholarly communication became much more interactive through the use of technologies as mundane as mailing lists or as sophisticated as collaboration tools.

In the early 1990s, the idea of the "digital library" was popularized, in part because of successful prototypes such as the A/ NSF/NASA grant program. Although the definition of the digital library continues to be debated, work under this grant program produced a number of very sophisticated information systems targeted at specific scholarly communities. For example, the Monarch/MARS digital library prototype was not directly connected to the efforts of academic library communities and were not intended to create models of the future of such institutions. Indeed, many of these digital libraries will not become digital libraries but rather will acquire access, on behalf of the users, to large-scale, ever-growing digital collections, including those of the "digital libraries" that will be developed by scholarly or commercial organizations.

Multimedia became a routine part of content and communication for learning and research: video, images, simulations, virtual reality walkthroughs, and audio are all carried by the Web. Instructional technology gave rise to digital "learning objects" that could be used in classroom settings or for independent learning.

Digital content also facilitated the creation of virtual "reserve rooms" and was harnessed to support distance education and asynchronous learning.

Expectations about services changed at this time. Capabilities such as personal views of collections of information resources, current awareness and change tracking systems, and recommender or collaborative filtering systems were developed for use on the Web for consumer use. Some of these also began to appear in library service offerings, though others, notably recommender systems, have not yet appeared, in part due to privacy concerns. And of course, library collections have transformed into network services and have become deeply integrated into campus information systems. Part of this evolution can be seen in the shifting relationships between libraries and campus information systems. In the first age of automation, the library could (and frequently did) stand alone; in the second age, the library became reliant on campus networking strategies; and in the third age, the library is critically dependent on both local-area and wide-area networks and on patron access to networked workstations and to network services as diverse as printing and authenticating. In the networked information revolution, libraries not only offer their own network-based services but are also becoming increasingly involved in the management and organization of external activities on the network.

This massive range of changes created enormous questions for libraries—perhaps most fundamentally about what constitutes the core of scholarly discourse that they must manage, provide access to, organize, acquire, and preserve and about what constitutes the raw material of future scholarship that must be cataloged, organized, and archived. Clearly, this goes far beyond the output of the traditional scholarly publishers and also goes far beyond the concepts of fixed, published, printed works. So much of the new content is network-based, produced outside the library and outside of the entire system of publishing that it is unclear how much responsibility the library should take for this material or how they should go about taking that responsibility.

At the same time, academic libraries face difficult problems about how to allocate scarce, increasingly expensive space. State for contracts, the Web is fast becoming our print heritage of past centuries and of our special collections in libraries and in the holdings of archives and museums. The scale and scope of this effort is vast, but so are the benefits to be gained.

Conclusions

Intellectually, automation is easy and comfortable, even seductive, because it reduces the time and effort involved in much routine work, but software is harnessed to support digi-
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Conclusions

Intellectually, automation is easy and comfortable, even seductive, because it reduces the time and effort involved in much routine work, but software is harnessed to support digital information; how to address questions of authenticity, integrity, and provenance; and how to structure services and information so that they are computationally manipulated rather than merely viewed.

Some issues now involve legislation and public policy. Intellectual property rights questions that will be important to the promise of the digital environment. The issue isn’t just paying for currently available intellectual property rights (books, storage robots and ultrafiche machines are two notable examples). They have been more skeptical and reluctant to adopt innovation (network access, new media, digital gen- res, personalization, and recom- mendee systems are good exam-
ple here)—though often they have had good cause for their caution. Libraries must now turn their attention to defining their missions and expertise and on the Web.

Establishing a new definition of the "canon" of scholarly communication and the library’s relation to it in terms of acquisition or selection, organization and management, access and preservation.

A Few Predictions for the Future

I predict that the following issues will be central for academic libraries in the early twenty-first century:

- Establishing a new definition of the "canon" of scholarly communication and the library’s relation to it in terms of acquisition or selection, organization and management, access and preservation.

- Addressing the problem of acquiring, managing, and preserving the raw materials for future scholarship as these materials become digital and as they diversify in character.

- Finding a new balance between centralization, collective action and local effort. In a world of shared resources on the network, it is possible to rethink the strategies for management, organization and description, and preservation of content, and economic considerations encourage such centralization. Yet there are also legitimate needs for local control and for responsiveness to local institutional needs.

- Defining the service boundaries of the library in a world where information is dynamic and is manipulated rather than simply presented to library users. Think about an information resource such as federal census data: in general, this is not simply viewed but rather is an object of computational analysis.

- Resolving the systemic funding problems in an environment where costs for traditional material resources are increasingly unsustainable and where libraries are simultane-
ously being confronted with the need to invest in the support of a range of nontradi-
tional networked information resources.

- Developing new roles for the library within the academic enterprise to meet the needs of the networked information revolution. These roles may well include teach-
ing information literacy and information resource evaluation; multimedia authoring and management; partnership with other institutions; projects and programs (though it is unclear whether this will involve the library as an institution or a new set of information specialists who are part of the research project teams); sup-
port of distance education planning and delivery through the development of new information resources; stewardship of instructional materials, particularly "learning objects"; rights and intellectual property management; and training and consultation in data structuring, representation, organization, and preservation.

The networked information revolu-
tion has arrived but is still in its infancy. I believe that we will spend the next decade really figuring out how to take advantage of this material and building up an ever-growing mass of content. This will include not only new materials that will be created and current resources that are rapidly moving into digital form but also the many manuscripts, photographs, and other records that are the work of past centuries and of our special collections in libraries and in the holdings of archives and museums. The scale and scope of this effort is vast, but so are the benefits to be gained.

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and activities in relationship to their transforming context—the information technology revolution in teaching, learning, and research. This will be much harder and more challenging than automation. And it will be a more reactive process: changes in scholarly communication practice, applications of instructional technology, and developments in intellectual property law will shape much of the future of the academic library.

It is striking to me that unlike the progress of automation (modernization) during the past thirty years, which focused on the implementation and management of technology, the agenda for the start of the next century is almost entirely dominated by addressing the effects and implications of technological change. It is, truly, transformation: a basic alteration in the activities of the academic library as an organization as a result of the new technological capabilities and the shifting context of higher education and scholarship.

Notes
1. This history has not yet really been written; for one window into the thinking of the time, see J. C. R. Licklider’s book Libraries of the Future (Cambridge: MIT Press, 1965). Licklider went on to ARPA and was instrumental in creating the ARPAnet, the predecessor of today’s Internet. For a survey that covers some of this early history, see also Clifford A. Lynch and Cecilia M. Preston, “Internet Access to Information Resources,” Annual Review of Information Science and Technology (ARIST), vol. 25 (New York: Elsevier, 1990), 263–312.
3. This is most true of historical material. By way of contrast, museums that acquire works by modern artists often get only the work, not the rights to reproduce the work. Using images of the work on postcards or in museum catalogs requires additional negotiation with, and additional payment to, the artist.