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 process 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
rational period characterized by the primacy of the systems analysis perspective and a focus on studies of cost benefit tradeoffs in the introduction of technology to modernize library operations. Starting in the late 1960s or early 1970s, academic libraries were confronted with environmental changes that required a change in technol- ogy, which quickly moved the focus of attention away from automa- tion toward a series of much more fundamental changes in the roles and missions in the digital age. Libraries were forced to react to developments in information technology (and their cultural and economic con- sequences) rather than methodically exploiting the full potential of the World Wide Web in the mid-1990s perhaps is the great symbol of this shift, with all of its implications for scholarly communication; but there is much more: the rise of computational science, the new role of databases in research; and the new century, libraries are strug- gling to absorb innovation and to rec- ognize the implications and meanings of transformation.

The First Automation Age: Computing Library Operations

T here 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. The first use of computerized libraries, this technology first arrived in force in the late 1960s or early 1970s in many academic or public libraries or commercial products intended to automate library processes. Minicom- puters were introduced to automate circulation functions and, very quickly, cataloging was also automated. Computer-based ordering sys- tems were introduced to pass orders to book suppliers with suppliers taking very careful changes simply made existing manual processes more efficient and helped to control their costs.

This was a period of significant management challenge for libraries. Many of the companies offering products were small; some used cus- tomer hardware and software, and a number of these companies failed. Some libraries developed their own systems rather than purchasing com- mercial products; yet few libraries had the expertise to manage large, operationally critical software proj- ects. Libraries also learned some hard lessons about system life-cycles and system ad- dministration. For example, the conver- sion from a manual circulation sys- tem to the first automated system was far easier than the conversion from the first automated circulation system to the second one, when some libraries discovered that there was no way to get information out of the old system and into the new one and found that the two systems were in parallel for a year or more. Perhaps the greatest achievement of this period, which continued until the early 1980s, was the development of shared copy-cataloging systems.

These systems established very important precedents in the use of computers and computer network- ing for collaboration and cooperation within the library community and paved the way for other key developments that would change libraries in the 1980s and early 1990s. These developments laid the foundation for the second one, when some libraries discovered that there was no way to get information out of the old system and into the new one and found that the two systems were in parallel for a year or more. Perhaps the greatest achievement of this period, which continued until the early 1980s, was the development of shared copy-cataloging systems.

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The first result of this next round of changes was the online public-

library catalog as a replace- ment for the traditional card catalog. The appearance of innovation, rather than monographs, are the key literature in many disciplines, particularly in the sci- ences, and that by the mid-1980s a typical research library was spending more than half of its acquisitions budget on journals, the library cata- log was unresponsive to the needs of many library patrons—particularly in the sciences. The online catalog was a huge advance. But it was almost com- pletely irrelevant to many library users. Traditionally, library catalogs have contained entries for books and access library catalog as a replace- ment for the traditional card catalog. 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The Third Automation Age: Print Content Goes Electronic

We are now in the third—and probably final—epoch of automation. Modernization has largely run its course, and new issues related to innovation and transformation are becoming dominant. Online catalogs, though wildly popular, rampant with bugs, and inflexible in real-time data entry, have undergone no fundamental change. Needles libraries had to enjoy the freedom of remote, twenty-four-hour-a-day access, they quickly grew frustrated with searches that ended with the identification of only “possible” material that they had to wait to get or that they could not get easily (e.g., if they were searching a catalog halfway across the world, at another institution). By the late 1980s and early 1990s, the costs of storage and maintenance of these systems became more complex, and libraries had to take a more strategic approach to managing their content. The idea of a single, integrated catalog covering all library materials was abandoned, and more localized solutions were implemented. However, the trend towards electronic content continued, and the use of the Internet for delivering catalog information increased significantly. Despite the challenges, libraries continued to invest in electronic content and to develop strategies for managing it. This period of innovation and transformation was marked by a growing recognition of the importance of digital media and the need for libraries to adapt to new technologies.
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, the social 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 such as personal views of collections of information resources, current awareness and change tracking systems, and recommender or collaborative filtering systems. In the early Web, these appeared to be 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 services. Part of this evolution can be seen in the shifting relationships between libraries and campus information technology. 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 authoring. In the networked information revolution, libraries not only offer their own network-based services but also are 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, what constitute 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 documented, 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 raw content is unstructured and 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 competitive, and expensive resources to these and the present and the future. The traditional published scholarly literature remains of critical importance, and its costs and volume continue to increase out of control. The late-nineteenth- and early-twentieth-century published literature, printed largely on acid paper, continues to disintegrate: there is an enormous need for investments in preservation. New materials have been added to the agenda: how to describe multimedia digital information effectively, and how to archive digital information; how to address questions of authenticity, integrity, and provenance; and how to structure digital information so that the needs of computational manipulations can be met. Services like personal views of collections and awareness and change tracking systems are now clearly one of the greatest challenges of the area, and as such, are two notable examples. They involve legislation and public policy. The great thing about automation is that you already know where you are heading and what you are trying to do. A very wise person in the late-nineteenth century mapped out the future along the automation timeline through the end of the millennium. Indeed, libraries have always been aggressive adopters of automation technologies—sometimes too aggressive (book-storage robots and ultramaticing indexing machines are two notable examples). They have been more skeptical and reluctant to adopt innovation (network access, new media, digital genres, personalization, and recommender systems are good examples here)—though often they have had good cause for their caution. Contrary to what many believe, libraries 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 services. Part of this evolution can be seen in the shifting relationships between libraries and campus information technology. 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 authoring. In the networked information revolution, libraries not only offer their own network-based services but also are becoming increasingly involved in the management and organization of external activities on the network.

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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, 1995), 203–312.
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.