Editor's Note

In the summer of 2024, Clifford Lynch announced his retirement as executive director of the Coalition for Networked Information (CNI) after 28 years at its helm. CNI quietly launched a project to create this Festschrift to document and honor his legacy. Authors began contributing articles in early 2025, with a planned publication date of July 2025. Since the final membership meeting of Cliff's tenure was April 7–8 in Milwaukee, the plan was to surprise him, surrounded by colleagues and friends, with a presentation of the table of contents of this special issue. However, just two weeks prior to the meeting, Cliff's health worsened; he was told about the Festschrift and received project details and articles. Though unable to attend in person, he participated in the CNI membership meeting via Zoom and also virtually joined his retirement reception, which included readings of excerpts from each article in this volume. Sadly, on April 10, 2025, Clifford Lynch passed away. Festschrift contributors wrote their articles prior to his passing, and we have chosen not to alter their original language.

Libraries, Digital Libraries, and Data: Forty Years, Four Challenges

Christine L. Borgman

abstract: *Digital libraries* is an umbrella term that encompasses the automation of library services, online catalogs, information retrieval systems, multimedia databases, data archives, and other Internet-facing collections of digital resources. Clifford Lynch has played pivotal roles in the technical development, institutionalization, policy, practice, and dissemination of digital libraries for more than 40 years. Beginning with his foundational role in building MELVYL for the University of California in the early 1980s—the first Internet-native online open access library catalog—through his convening roles in open access and open data in the twenty-first century, his career is marked by multiple milestones of innovation. Clifford Lynch's career has traced the trajectory of digital libraries and knowledge infrastructures. Over the course of these 40 years, research libraries have faced four categories of challenges: invisible infrastructure, content and collections, preservation and access, and institutional boundaries. These challenges have become yet more complex in an era of open access, open data, and evolving regimes of intellectual property and scholarly publishing. As the digital library communities have merged and diverged over this time span, we collectively face challenges for at least the next 40 years to sustain access to current resources while growing the next generations of digital libraries and librarians.

The Dawn of Online Catalogs

Clifford began his pioneering career in research libraries when he joined the University of California Division of Library Automation (UC-DLA) in 1979 to lead the development of MELVYL, the first major online library catalog designed for Internet access.[1] In these early days, universities were constructing their own automated library systems for access via campus networks or dial-up modems. The nascent market for automated library systems did not yet scale up to the needs of large, distributed institutions, whether university or public libraries.

portal: Libraries and the Academy, Vol. 25, No. 3 Supplement (2025), pp. 39–58.

Following a path parallel to Clifford, the author began her career in library automation as systems analyst for the Dallas Public Library, with primary responsibility for developing an online catalog. Written in assembler language on the City of Dallas mainframe computer system, the catalog went live for patron access in late 1978 on CRT (cathode ray tube) terminals.[2]

Also in 1980, the Council on Library Resources (CLR, which became the Council on Library and Information Resources [CLIR] after merging with Commission on Preservation and Access) funded the first major study of online public access catalogs.[3] (The terms *online public access catalog* and the associated acronym, OPAC, were coined by the study participants.) Partners in the CLR collaboration included UC-DLA, the Research Libraries Group (RLG), OCLC (then known as the Ohio College Library Center), and the Library of Congress. The Research Libraries Group later was acquired by OCLC, and their databases were merged. Clifford was the delegate for the University of California. I was a delegate for RLG, based at Stanford University, where I was a doctoral student and research assistant on the OPAC project. Later I represented OCLC in several OPAC studies.[4] The CLR study laid the groundwork for technology, governance, and usability of automated library systems as the market and technologies began to mature.[5] Our collaboration on the CLR study led to a 40-year conversation with Clifford about libraries, information technologies, infrastructures, institutions, policies, and much else.

Emerging Knowledge Infrastructures

Only in the early 1990s, as the Cold War ended and as Western countries lifted their technology blockades to the Soviet Bloc, did the Internet become a functioning international infrastructure with open interconnections across countries and sectors. MELVYL, as the first Internet-facing online library catalog and probably the largest, included resources from what were then the nine campuses of the University of California (UC). MELVYL became an international digital library. During my years of teaching library automation and information retrieval at UCLA, beginning in 1983, and as a Fulbright Professor in Budapest in 1993, MELVYL was a primary instructional tool. The UC-wide catalog offered far more resources and search capabilities than anything else publicly available at the time, especially in Hungary or Central and Eastern Europe.

While Al Gore did not invent the Internet, as an oft-refuted urban legend claims, he did play important roles in information policy that enabled international network interconnections.[6] At the Inaugural World Telecommunication Development Conference in 1994, the new policy was announced as the Global Information Infrastructure (GII).[7] As the GII became a functioning infrastructure, the library world was well positioned to take advantage.[8] The vision of the GII as a "global digital library" built upon investments by the library community in technology, standards, institutions, and infrastructure, such as the MARC (machine-readable cataloging) format, Text Encoding Initiative, Dublin Core metadata, Unicode, OCLC, and RLG. National libraries also played important roles in developing information infrastructure within and between countries. Clifford was on the front lines of the GII, writing about such topics as research integrity, persistent identifiers, search technologies, and digitization.[9] All the while, he was advancing the digital library services of the University of California and pursuing his doctorate in computer science at Berkeley.

As terms such as *information infrastructure* came into common usage, scholars began to explore the historical origins of infrastructure in railroads, radio, telecommunications, finance, and other sectors.[10] Infrastructures are comprised of interacting technical, institutional, policy, and social components that evolve over time. Susan Leigh Star and Karen Ruhleder, taking a socio-technical perspective, identified eight dimensions of infrastructure, a model commonly recognized in the information science community. In their model, infrastructures are (1) embedded in other social arrangements and technologies; (2) transparent, supporting tasks invisibly; (3) spatial or temporal in scope; (4) learned as part of membership in an organization; (5) linked with conventions of practice in regular work; (6) an embodiment of standards; (7) built upon an installed base, inheriting capacity and limitations; and (8) become visible upon breakdown, when they cease to function as expected.[11] Concerns for libraries, digital libraries, and data are now subsumed in the context of knowledge infrastructures—defined as "robust networks of people, artifacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds."[12]

Clifford was on the front lines of the GII, writing about such topics as research integrity, persistent identifiers, search technologies, and digitization.

The mid-1990s were optimistic times for library technologies, but online public access catalogs (OPACs) were fledgling systems that remained difficult to use.[13] In response to a groundswell of interest in advancing information retrieval technologies, a coalition of 10 United States funding agencies, led by the National Science Foundation, launched a 10-year (1994–2004) multidisciplinary funding program known as the Digital Libraries Initiative (DLI).[14] UC-Berkeley was among the funding recipients, and again Clifford played a role. Of the countless number of papers resulting from 10 years of the DLI, the best known is the PageRank algorithm that became the basis of Google Search, initially a poster presentation at a DLI all-hands meeting at Stanford University.[15] Sergei Brin and Larry Page, who created Google as a DLI project, were doctoral students in computer science at Stanford under the supervision of Hector Garcia-Molina and Terry Winograd. Similarly influential within the digital libraries community was the research agenda that established basic principles for interoperability and infrastructure.[16] Clifford Lynch and Hector Garcia-Molina later revisited these interoperability issues as technology evolved.[17]

It was during the DLI that Paul Evan Peters, founding director of the Coalition for Networked Information (CNI), died suddenly. Clifford was the only imaginable candidate with the breadth of knowledge and deep engagement in the community to step into the CNI role in 1997. We in the University of California were sorry to lose him, but he remains close to the community. Clifford frequently visited UCLA to guest-lecture my library technology courses and to meet with others on campus. As of this writing, Michael Buckland and Clifford continue to offer a Friday afternoon seminar at UC-Berkeley on information systems.

Diverging Communities

While the DLI was a coalition of libraries and computer science researchers, the focus of these communities soon began to diverge. By the latter 1990s, computer scientists were

framing digital libraries as advanced information retrieval systems that supported content in multiple media. Libraries, in contrast, viewed digital libraries more holistically in terms of serving the information needs and uses of user communities.[18]

The latter 1990s, in Clifford's early years as director of CNI, were marked by a series of existential challenges to research libraries. In the 1970s era of library automation, computer scientists too often asked, "Why does the library need a computer?" Twenty years later, the next generation of computer scientists—and some university leaders—asked the inverse question, "Now that we have computers, why do we need libraries?" Clifford addressed these challenges head-on in a series of papers aimed at library, technology, academic, and policy audiences.[19] In these and other talks and papers, Clifford was among the first to address questions of authenticity, integrity, and digital stewardship as concerns of policy and practice. Assessing the past and future of digital libraries, Clifford commented that the term *digital library* had become an oxymoron, disconnected from libraries as institutions or the practice of librarianship.[20]

. . . Clifford was among the first to address questions of authenticity, integrity, and digital stewardship as concerns of policy and practice.

Clifford's public talks were already legendary, anticipating technology and policy trends several years out. Also legendary was his travel schedule, flying around the globe to attend conferences and meetings on countless topics related to networked information. Clifford is the ultimate networked individual who transports news across community boundaries. No amount of reading about current developments in information technology and policy could result in as much knowledge acquisition as listening to one of his talks or better yet, a long after-hours discussion. He is among the few speakers who can present a coherent framework over the course of an hour, from a few bullet points jotted on a notecard. Until video recording became common practice, few artifacts—and no slide decks—of those influential talks remain.

In the three decades since the launch of the DLI, research on digital libraries has expanded across domains of knowledge and communities incorporating content in more media, both digitized and born digital. The Joint Conference on Digital Libraries (JCDL) series launched in 2001 as a partnership of two computer science societies, the Association for Computing Machinery and Institute of Electrical and Electronics Engineers (IEEE) with the explicit goal of bringing the library and computer science communities together.[21] Later efforts diverged, with JCDL becoming dominated by computer science and engineering research, where much more funding for research and travel is available. JCDL continues to attract international participants and holds conferences in the United States and abroad. It was joined by the European Conference on Digital Libraries (ECDL) (later known as the the International Conference on Theory and Practice of Digital Libraries, TPDL), the International Conference on Asian Digital Libraries (ICADL), and numerous smaller conferences and workshops that bridge communities.

Four Challenges for Libraries

While the growth of research and publishing in digital libraries advanced the technological frontier for multiple economic sectors, public concern focused largely on the *digital* rather than on *libraries*. The library community was decreasingly visible in conferences and journals about digital libraries. As we entered the twenty-first century, four challenges for libraries in a digital age came into view: (1) invisible infrastructure, (2) content and collections, (3) preservation and access, and (4) institutional boundaries.[22] None of these challenges are yet resolved, 25 years on. Rather, they have changed in form and scale over time, becoming ever more critical for the future of libraries and librarianship.

Invisible Infrastructure

By the year 2000, a troubling refrain was emerging, perhaps common to all except humanities scholars, that people no longer visit the library because everything they need is online.[23] A defining characteristic of infrastructure is that it is invisible until it breaks down.[24] Invisibility is a sign of success, in that libraries were serving their communities so effectively that their existence was receding into the background. Invisibility is also a sign of failure, in that the substantial expertise, labor, and resources necessary to provide those services goes unrecognized. In times of shrinking budgets, invisibility is especially dangerous.

The work of Clifford and CNI has been essential to maintaining the visibility of library systems and services in the broader educational and policy communities. Access to information is seamless only to the extent that systems are interoperable, which requires substantial investments in technical standards, and deep expertise in knowledge organization. Technologies and partnerships that developed in the first two decades of the twenty-first century, such as digital object identifiers (DOI), Open Researcher and Contributor ID (ORCID), and Crossref, are the foundation for today's access to bibliographic content. They have become the invisible plumbing of knowledge infrastructures to those outside the library and information technology community.

The work of Clifford and CNI has been essential to maintaining the visibility of library systems and services in the broader educational and policy communities.

Content and Collections

The rise of digital libraries put the notion of library collections into sharp relief.[25] Research libraries were less able to compete for status based on the sheer number of volumes they acquired. Access to content, whether owned, licensed, or linked, became a growing concern. Here again, Clifford helped to lay the intellectual groundwork for maintaining the coherence of library collections, whether physical or digital, local or remote.[26] As the library and computer science communities diverged, so did concerns for coherent knowledge organization. Libraries catalog materials they acquire to sup-

port the information needs of their communities. They have far less control over how remotely accessed content is organized. Library catalogs increasingly are subsumed under content management systems, and users find their way into many of these resources via search engines external to library control.

Clifford helped to lay the intellectual groundwork for maintaining the coherence of library collections, whether physical or digital, local or remote.

Preservation and Access

Despite the lack of agreement on what constitutes a library "collection," the need to preserve collections in ways that they remain accessible became a growing challenge. Here again, Clifford waded through the sea of definitions of *preservation* and *access* to offer a path forward.[27] He called attention to the crises ahead as physical materials were crumbling and as publishers controlled access to digital content, without assurances of sustaining the viability of those resources. As a member of several study panels convened by the U.S. National Academies, Clifford made sure that concerns of the research library community were represented.[28] The lack of coherent economic and policy models for preserving and sustaining access to digital collections remains a massive problem for libraries—past, present, and future.

Institutional Boundaries

Collectively known as *memory institutions*, libraries, museums, and archives are tasked with organizing, preserving, and providing access to knowledge in various forms. Despite their common interests, each of these institutions has distinct histories, practices, and theoretical frameworks for collecting and organizing knowledge. Digitization has blurred the boundaries between types of artifacts, such as books, records, and objects, and between institutions. Determining who collects what kinds of content and who sustains access for future generations becomes even more complex when publishers lease access to content, and as research data repositories are hosted by funding agencies or as independent entities. The CNI community has broadened their tent over the last several decades to include more stakeholders from archives, museums, data repositories, publishing, technology, and policy to negotiate boundaries and partnerships.[29]

Open Access, Open Data

Electronic publishing began in earnest in the 1990s and became the norm by the early twenty-first century, contributing to massive changes in the publishing industry and in library services.[30] Scholars initially lacked trust in online journals, leading to hybrid journals published in both print and digital form, and to complex debates over which edition constitutes "the version of record." By 2001, Clifford was exploring "the future of the book" as a metaphor for rethinking the roles of cultural artifacts and intellectual property in an increasingly digital world.[31]

The apparent ease of digital distribution obscured the labor and costs involved in scholarly publishing, leading to claims that "information wants to be free" … and ex-

pensive, an aphorism attributed to Stewart Brand.[32] Anarchy in the early days of digital publishing gradually gave way to massive restructuring of the publishing industry and to many flavors of open access distribution. Setting aside complex formulas of who pays for what, when, and how, a simple definition of *open access* is that content is free to the reader. Various colors of open access are now the norm in scholarly publishing, promoted by governments and funding agencies in much of the world.

Open access and related developments in scholarly communication brought opportunities to research libraries but also wrought restructuring across the four challenges identified in the previous section.[33] Library investments in infrastructure continued to expand as collections diversified in format, content, and contract. Sustaining access to materials not owned by library institutions was a growing problem. Memory institutions began to work more closely across boundaries on matters of knowledge organization and access. Again, Clifford and CNI gave voice to library perspectives on digital preservation, institutional repositories, economics of digitization, misinformation, and university roles in disseminating scholarship.[34]

. . . Clifford and CNI gave voice to library perspectives on digital preservation, institutional repositories, economics of digitization, misinformation, and university roles in disseminating scholarship.

Educational implications of knowledge infrastructures were another growing concern in the first decade of the twenty-first century. CNI provides a bridge between research libraries and university infrastructure as a partnership between the Association of Research Libraries and EDUCAUSE. This partnership was leveraged to good effect by addressing new models for learning and for open educational resources made possible by new infrastructure investments.[35]

Roughly parallel in time with the growth of open access publishing, if somewhat slower to reach critical mass, was growth in open data policies. Open data, in the simplest definition, is releasing datasets associated with scholarly publications.[36] Digital datasets are an unusual category of materials that rarely are collected by libraries, archives, or museums. Discipline-specific data archives, where they exist, are the more common home for such resources. Data formats, content, and scale vary by orders of magnitude from astronomy to archaeology, and for everything in between. CNI and Clifford addressed these challenges to universities early on, articulating characteristics of, and requirements for, stewarding datasets.[37]

Managing research data is a growing priority for the scholarly enterprise, leading to broader concerns for research data infrastructure.[38] Funding agency requirements for sharing research data are based on solid arguments for leveraging investments in research, promoting transparency, and reproducibility of findings.[39] However, individual researchers often have few incentives to share their data. They also have valid concerns about misuse, misinterpretation, and misappropriation of their work. Making research data FAIR (findable, accessible, interoperable, and reusable) remains complex, labor-intensive, and expensive in most disciplines.[40] Making research data sustainable for the

long term involves an array of economic, social, institutional, and infrastructural challenges. The lack of sufficient data management workforce comprised of data librarians and archivists is central to these challenges.

The Next 40 Years

Online public access catalogs were known initially as "online card catalogs," reflecting the technological transition underway. Few of today's students grew up with card catalogs, making card-based user interfaces appear antiquated. Librarians have invested more than 40 years of labor in adapting standards and practices for knowledge organization to a world of digital content and networked institutions.[41] An existential challenge for libraries is to maintain continuity with centuries of cataloging practice while developing modern practices that interoperate with technical standards developed (and controlled) by other agencies, such as the World Wide Web Consortium.

Today's generation of "digital natives" bring their knowledge of search engines and web-based interfaces to library catalogs and databases. User training in online searching is a foregone task.[42] However, keyword searching alone is insufficient to exploit the full power of library cataloging systems that employ nuanced distinctions between editions, formats, languages, similar author names, and other bibliographic details. Library users who employ skills learned on web search engines rarely know what they are missing unless they consult librarian experts. A larger concern is that many library users assume that everything they need exists online, in digital form. Vast amounts of valuable scholarly material exist only in physical form, large portions of which are minimally described or remain uncataloged. Hidden collections abound. When cultural collections are lost due to fires, flood, climate change, war, or other disasters, the world may lack records of what existed. More than 20 years ago, Clifford warned us of the coming crisis in sustaining access to these resources, proposing digitization at least as backup against disaster.[43]

A looming challenge for the next 40 years is how to sustain access to the vast resources of digital and digitized content now held by libraries, museums, archives, governments, business, and individuals. Most physical artifacts such as books and journals can survive by benign neglect. Digital resources survive only by continual refreshment and migration to new technologies. Research datasets are especially fragile because they often rely on custom software tools and platforms that evolve rapidly.[44] Underlying these infrastructural challenges for sustaining access to scholarship are human resource constraints. The necessary workforce of skilled librarians, data managers, data archivists, and data curators is sorely lacking in universities, research domains, and in other sectors of the economy. This problem is not new, nor are the reasons for the lack of workforce investment simple.[45]

More than 20 years ago, Clifford warned us of the coming crisis in sustaining access to these resources, proposing digitization at least as backup against disaster

The better the technology and infrastructure, the less inherent is visibility of the investments made by libraries and librarians. More than ever, CNI and other library leaders must make visible the invisible roles of their institutions.

Acknowledgments

The historical framing in this article is based loosely on my keynote presentation to the 2024 Conference on Theory and Practice of Digital Libraries, in Ljubljana, Slovenia;[46] thanks are due to Gianmaria Silvello, Ines Vodopivec, and the National and University Library of Slovenia for the invitation and conference hosting. I cherish my 45-year friendship with Clifford, his many insights in our long and frequent conversations, and his generous editing and advising on all three of my MIT Press books.[47]

For those readers accustomed to the more readable APA format of publication, the author's version of this article is available open access in the University of California eScholarship Repository at https://escholarship.org/uc/item/6dn9z9k6 and also will be available in arXiv.org.

Christine L. Borgman is Distinguished Research Professor in Information Studies at the University of California, Los Angeles; she may be reached by email at Christine.Borgman@UCLA.edu.

Notes

1. Mike Ashenfelder, "Digital Preservation Pioneer: Clifford Lynch," *The Signal: Digital Preservation (Library of Congress)*, May 29, 2013, http://blogs.loc.gov/digitalpreservation/2013/05/digital-preservation-pioneer-clifford-lynch/?goback=%2Egde_4158855_member_245450802.
2. Christine L. Borgman, "Library Automation at Dallas Public Library," in *Information Management in the 1980's: Proceedings of the ASIS Annual Meeting 1977 Volume 14 : 40th Annual Meeting, Chicago, Illinois, September 26-October 1, 1977*, ed. Bernard M. Fry and Clayton A. Shepherd, vol. 14, American Society for Information Science (White Plains, NY: Knowledge Industry Publications for American Society for Information Science, 1977), 2-A9-A-14 Microfilm; Christine L. Borgman and Neal K. Kaske, "Determining the Number of Terminals Required for an On-Line Catalog through Queueing Analysis of Catalog Traffic Data," *Clinic on Library Applications of Data Processing (17th : 1980)*, 1980, https://hdl.handle.net/2142/1110.
3. Davis B. McCarn, *Online Catalogs: Requirements, Characteristics, and Costs* (Washington, DC: Council on Library Resources, 1983); Research Libraries Group, "Public Online Catalogs and Research Libraries: Final Report to the Council on Library Resources" (Stanford, CA: 1982).
4. Christine L. Borgman, *Research Report Prepared for OCLC on End User Behavior on the Ohio State University Libraries' On-Line Catalog: A Computer Monitoring Study*, OCLC 9891430 (Dublin, OH: OCLC, 1983); Christine L. Borgman, "The User's Mental Model of an Information Retrieval System: An Experiment on a Prototype Online Catalog," *International Journal of Man-Machine Studies* 24, 1 (January 1, 1986): 47–64, https://doi.org/10.1016/S0020-7373(86)80039-6.
5. Thomas R. Kochtanek and Joseph R. Matthews, *Library Information Systems: From Library Automation to Distributed Information Access Solutions* (Westport, CT: Libraries Unlimited, 2002); Joseph R. Matthews, *Public Access to Online Catalogs: A Planning Guide for Managers* (Weston, CT: Online Inc., 1982).
6. Michael Kronenfeld and Jennie J. Kronenfeld, "Al Gore, the Internet and the National Library of Medicine," *Circulating Now from the NLM Historical Collections*, July 2, 2020, https://circulatingnow.nlm.nih.gov/2020/07/02/al-gore-the-internet-and-the-national-library-of-medicine/.

7. Albert Gore, "Inauguration of the First World Telecommunication Conference" (World Telecommunication Development Conference, Buenos Aires, Argentina, 1994), https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/4.144.57.en.104.pdf.
8. Christine L. Borgman, *From Gutenberg to the Global Information Infrastructure: Access to Information in the Networked World* (Cambridge, MA: MIT Press, 2000).
9. Clifford A. Lynch, "Reaction, Response, and Realization: From the Crisis in Scholarly Communication to the Age of Networked Information," *Serials Review* 18, 1–2 (March 1992): 107–12, https://doi.org/10.1080/00987913.1992.10764063; Clifford A. Lynch, "The Integrity of Digital Information: Mechanics and Definitional Issues," *Journal of the American Society for Information Science* 45, 10 (1994): 737–44, https://doi.org/10.1002/(SICI)1097-4571(199412)45:10<737::AID-ASI4>3.0.CO;2-8; Clifford A. Lynch, "Searching the Internet," *Scientific American* 276 (March 1997): 52–56, https://doi.org/10.1038/scientificamerican0397-52; Clifford A. Lynch, "Identifiers and Their Role in Networked Information Applications," *Bulletin of the American Society for Information Science* 24, 2 (1998): 17–20, https://doi.org/10.1002/bult.80; Clifford A. Lynch, "From Automation to Transformation: Forty Years of Libraries and Information Technology in Higher Education," *EDUCAUSE Review* 35, 1 (2000): 60-; Clifford A. Lynch and Edwin B. Brownrigg, "Library Applications of Electronic Imaging Technology," *Information Technology and Libraries* 5, 2 (1986): 100–105; Sue Tyner and Clifford A. Lynch, "University of California Union Catalog: An Overview of Bibliographic Issues," in *Communicating Information: Proceedings of the 43rd ASIS Annual Meeting*, ed. A. R. Benenfeld and Edward J. Kazlauskas (ASIS Annual Meeting, Anaheim, CA, 1980), 266–69.
10. Ronald H. Brown, Larry Irving, Arati Prabhakar, and Sally Katzen, "The Global Information Infrastructure: Agenda for Cooperation," National Technical Information Agency, 1995, http://www.ntia.doc.gov/reports/giiagend.html; Paul A. David, "Towards a Cyberinfrastructure for Enhanced Scientific Collaboration: Providing Its 'Soft' Foundations May Be the Hardest Part" (Stanford, CA: Stanford Institute for Economic Policy Research, 2005), http://www-siepr.stanford.edu/papers/pdf/04-01.pdf; Paul N. Edwards, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems," in *Modernity and Technology* (Cambridge, MA: MIT Press, 2003); Amy Friedlander, "Emerging Infrastructure: The Growth of Railroads" (Reston, VA: Corporation for National Research Initiatives, 1995), http://www.cnri.reston.va.us/series.html#rail; Amy Friedlander, "Natural Monopoly and Universal Service: Telephones and Telegraphs in the U.S. Communications Infrastructure 1837–1940" (Reston, VA: Corporation for National Research Initiatives, 1995), http://www.cnri.reston.va.us/series.html#teltel; Amy Friedlander, "'In God We Trust': All Others Pay Cash" (Reston, VA: Corporation for National Research Initiatives, 1996), http://www.cnri.reston.va.us/series.html#bank; Amy Friedlander, "Power and Light: Electricity in the U.S. Energy Infrastructure, 1870–1940" (Reston, VA: Corporation for National Research Initiatives, 1996), http://www.cnri.reston.va.us/series.html#power; Amy Friedlander, "Communications and Content: Radio Technologies in the U.S. Infrastructure, 1865–1976" (Reston, VA: Corporation for National Research Initiatives, 2005), http://www.cnri.reston.va.us/series.html#radio; Joint Information Systems Committee, "Leveraging Shared Infrastructure and Expertise to Develop Digital Projects in an Academic Department: Centre for Computing in the Humanities," April 24, 2009, 1–8; David Ribes and Thomas Finholt, "The Long Now of Technology Infrastructure: Articulating Tensions in Development," *Journal of the Association for Information Systems* 10, 5 (May 28, 2009), https://doi.org/10.17705/1jais.00199; David Ribes and Charlotte P. Lee, "Sociotechnical Studies of Cyberinfrastructure and E-Research: Current Themes and Future Trajectories," *Computer Supported Cooperative Work (CSCW)* 19, 3 (August 1, 2010): 231–44, https://doi.org/10.1007/s10606-010-9120-0.
11. Susan Leigh Star and Karen Ruhleder, "Steps toward an Ecology of Infrastructure: Design and Access for Large Information Spaces," *Information Systems Research* 7, 1 (March 1996): 111–34, https://doi.org/10.1287/isre.7.1.111.

12. Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010), 17.
13. Christine L. Borgman, "Why Are Online Catalogs Hard to Use? Lessons Learned from Information-Retrieval Studies," *Journal of the American Society for Information Science* 37, 6 (November 1986): 387–400, https://doi.org/10.1002/(SICI)1097-4571(198611)37:6<387::AID-ASI3>3.0.CO;2-8; Christine L. Borgman, "Why Are Online Catalogs Still Hard to Use?" *Journal of the American Society for Information Science* 47, 7 (1996): 493–503, https://doi.org/10.1002/(SICI)1097-4571(199607)47:7<493::AID-ASI3>3.0.CO;2-P.
14. "Digital Libraries," National Science Foundation, 1999, https://www.nsf.gov/news/news_summ.jsp?cntn_id=103048; Stephen M. Griffin, "NSF/DARPA/NASA Digital Libraries Initiative: A Program Manager's Perspective," *D-Lib Magazine* 4 (July–August 1998), https://www.dlib.org/dlib/july98/07griffin.html.
15. Sergey Brin and Lawrence Page, "The Anatomy of a Large-Scale Hypertextual Web Search Engine," *Computer Networks and ISDN Systems*, Proceedings of the Seventh International World Wide Web Conference 30, 1 (April 1, 1998): 107–17, https://doi.org/10.1016/S0169-7552(98)00110-X.
16. Clifford A. Lynch and Hector Garcia-Molina, "Interoperability, Scaling, and the Digital Libraries Research Agenda," IITA (Information Infrastructure Technology and Applications) Digital Libraries Workshop, 1995, http://www-diglib.stanford.edu/diglib/pub/reports/iita-dlw/main.html.
17. Tony Hey, Herbert Van de Sompel, Don Waters, Cliff Lynch, and Carl Lagoze, "Augmenting Interoperability across Scholarly Repositories," in *Proceedings of the 6th ACM/IEEE-CS Joint Conference on Digital Libraries*, JCDL '06 (New York: Association for Computing Machinery, 2006), 85, https://doi.org/10.1145/1141753.1141768; Clifford A. Lynch and Hector Garcia-Molina, "Retrospective: The 1995 Interoperability, Scaling, and the Digital Libraries Research Agenda Report" (DLI2/IMLS/NSDL Principal Investigators Meeting, 2002), http://www.dli2.nsf.gov/dli2pi2002/program.html.
18. Christine L. Borgman, "What Are Digital Libraries? Competing Visions," *Information Processing & Management* 35, 3 (May 1999): 227–43, https://doi.org/10.1016/S0306-4573(98)00059-4.
19. Lynch, "Searching the Internet"; Lynch, "From Automation to Transformation"; Clifford A. Lynch, *The Academic Library in the Networked Information Age, Preparing Your Campus for a Networked Future* (San Francisco: Jossey-Bass, 2000); Clifford A. Lynch, "The Battle to Define the Future of the Book in the Digital World," *First Monday*, June 4, 2001, https://doi.org/10.5210/fm.v6i6.864; Clifford A. Lynch, "When Documents Deceive: Trust and Provenance as New Factors for Information Retrieval in a Tangled Web," *Journal of the American Society for Information Science and Technology* 52, 1 (2001): 12–17, https://doi.org/10.1002/1532-2890(2000)52:1<12::AID-ASI1062>3.0.CO;2-V; Clifford A. Lynch, "Digital Collections, Digital Libraries and the Digitization of Cultural Heritage Information," *First Monday*, May 6, 2002, https://doi.org/10.5210/fm.v7i5.949; Clifford A. Lynch, "The Afterlives of Courses on the Network: Information Management Issues for Learning Management Systems," *EDUCAUSE Center for Applied Research: Research Bulletin* 2002 (November 26, 2002); Clifford A. Lynch, "Colliding with the Real World: Heresies and Unexplored Questions about Audience, Economics, and Control of Digital Libraries," in *Digital Library Use: Social Practice in Design and Evaluation*, ed. Ann Peterson Bishop, Nancy Van House, and Barbara P. Buttenfield (Cambridge, MA: MIT Press, 2003), 191–216; Clifford A. Lynch, "Institutional Repositories: Essential Infrastructure for Scholarship in the Digital Age," *ARL Bimonthly Report*, February 2003, 1–7, http://www.arl.org/newsltr/226/ir.html; Clifford A. Lynch, "Life after Graduation Day: Beyond the Academy's Digital Walls," *EDUCAUSE Review* 38 (October 2003): 12–13; Clifford A. Lynch, "Preserving Digital Documents: Choices, Approaches, and Standards," *Law Library Journal* 96 (2004): 609–17, http://www.aallnet.org/products/pub_llj_v96n04.asp.

20. Clifford Lynch, "Where Do We Go From Here? The Next Decade for Digital Libraries," *D-Lib Magazine* 11, 7–8 (July 2005), https://doi.org/10.1045/july2005-lynch.
21. Christine L. Borgman and Heather Hessel, "Report on the First Joint Conference on Digital Libraries," *D-Lib Magazine* 7 (2001), http://www.dlib.org/dlib/october01/borgman/10borgman.html; Edward A. Fox and Christine L. Borgman, eds., *Proceedings of First ACM/IEEE-CS Joint Conference on Digital Libraries June 24-28, 2001: Roanoke, Virginia, USA* (New York: ACM Press, 2001), http://uclibs.org/PID/32583.
22. Borgman, *From Gutenberg to the Global Information Infrastructure*; Christine L. Borgman, "The Premise and Promise of a Global Information Infrastructure," *First Monday* 5, 8 (August 7, 2000), https://doi.org/10.5210/fm.v5i8.784; Christine L. Borgman, "The Invisible Library: Paradox of the Global Information Infrastructure," *Library Trends* 51 (2003): 652–74, http://hdl.handle.net/2142/8487.
23. Borgman, "The Invisible Library."
24. Star and Ruhleder, "Steps Toward an Ecology of Infrastructure."
25. Michael K. Buckland, *Library Services in Theory and Context*, 2nd ed. (Oxford: Pergamon, 1988); Michael K. Buckland, *Redesigning Library Services: A Manifesto* (Chicago: American Library Association, 1992), https://hdl.handle.net/2027/mdp.39015027238693.
26. Clifford A. Lynch, "Today & Tomorrow: What the Digital Library Really Means for Collections & Services," in *Virtually Yours: Models for Managing Electronic Resources and Services*, ed. Peggy Johnson and Bonnie MacEwan, vol. 8, ALCTS Papers on Library Technical Services and Collections (Chicago: American Library Association, 1999), 85–97, https://www.cni.org/publications/cliffs-pubs/what-the-digital-library-really-means.
27. Clifford A. Lynch, "The Role of Digitization in Building Electronic Collections: Economic and Programmatic Choices," *Collection Management* 22, 3–4 (May 27, 1998): 133–41, https://doi.org/10.1300/J105v22n03_12; Lynch, "Digital Collections, Digital Libraries and the Digitization of Cultural Heritage Information"; Clifford A. Lynch, "The Coming Crisis in Preserving Our Digital Cultural Heritage," *Journal of Library Administration* 38, 3–4 (June 1, 2003): 149–61, https://doi.org/10.1300/J111v38n03_04.
28. Blue Ribbon Task Force on Sustainable Digital Preservation and Access, "Sustainable Economics for a Digital Planet: Ensuring Long-Term Access to Digital Information," Final Report, February 2010, http://brtf.sdsc.edu/biblio/BRTF_Final_Report.pdf; *LC21: A Digital Strategy for the Library of Congress* (Washington, DC: National Academies Press, 2000), https://doi.org/10.17226/9940; National Academies of Sciences, Engineering, and Medicine, *Life-Cycle Decisions for Biomedical Data: The Challenge of Forecasting Costs* (Washington, DC: National Academies Press, 2020), https://doi.org/10.17226/25639.
29. National Research Council, *Preparing the Workforce for Digital Curation* (Washington, DC: National Academies Press, 2015), http://www.ncbi.nlm.nih.gov/books/NBK293663/; Mary Lee Kennedy and Clifford A. Lynch, "A Case for Continued Strategic Investments by Research Libraries to Advance Research and Learning," *Association of Research Libraries* (blog), July 10, 2020, https://www.arl.org/news/a-case-for-continued-strategic-investments-by-research-libraries-to-advance-research-and-learning/; Lynch, *The Academic Library in the Networked Information Age, Preparing Your Campus for a Networked Future*; Lynch, "Life after Graduation Day: Beyond the Academy's Digital Walls"; Clifford A. Lynch, "Open Computation: Beyond Human Reader-Centric Views of Scholarly Literatures," chap. 19 in *Open Access: Key Strategic, Technical and Economic Aspects*, ed. Neil Jacobs (Oxford, UK: Chandos, 2006), 185–95, http://www.cni.org/staff/cliffpubs/OpenComputation.htm; Clifford A. Lynch, "The Next Generation of Challenges in the Curation of Scholarly Data," in *Research Data Management: Practical Strategies for Information Professionals*, ed. Joyce M. Ray (West Lafayette, IN: Purdue University Press, 2013); Clifford A. Lynch, "Stewardship in the 'Age of Algorithms,'" *First Monday*, December 2, 2017, https://doi.org/10.5210/fm.v22i12.8097.
30. Christine L. Borgman, *Scholarship in the Digital Age: Information, Infrastructure, and the Internet* (Cambridge, MA: MIT Press, 2007).

31. Lynch, "The Battle to Define the Future of the Book in the Digital World."
32. R. Polk Wagner, "Information Wants to Be Free: Intellectual Property and the Mythologies of Control," *Columbia Law Review*, January 1, 2003, https://scholarship.law.upenn.edu/faculty_scholarship/742.
33. Borgman, *Scholarship in the Digital Age*.
34. Lynch, "When Documents Deceive"; Lynch, "Digital Collections, Digital Libraries and the Digitization of Cultural Heritage Information"; Lynch, "Colliding with the Real World: Heresies and Unexplored Questions about Audience, Economics, and Control of Digital Libraries"; Lynch, "Institutional Repositories: Essential Infrastructure for Scholarship in the Digital Age"; Lynch, "The Coming Crisis in Preserving Our Digital Cultural Heritage"; Lynch, "Preserving Digital Documents: Choices, Approaches, and Standards"; Clifford A. Lynch and Joan K. Lippincott, "Institutional Repository Deployment in the United States as of Early 2005," *D-Lib Magazine* 11, 9 (September 2005), https://doi.org/10.1045/september2005-lynch.
35. NSF Task Force on Cyberlearning, "Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge. A 21st Century Agenda for the National Science Foundation" (Washington, DC: National Science Foundation, June 24, 2008), https://www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf; Lynch, "The Afterlives of Courses on the Network: Information Management Issues for Learning Management Systems"; Lynch, "Life after Graduation Day: Beyond the Academy's Digital Walls."
36. Christine L. Borgman, *Big Data, Little Data, No Data: Scholarship in the Networked World* (Cambridge, MA: MIT Press, 2015); Irene V. Pasquetto, Ashley E. Sands, Peter T. Darch, and Christine L. Borgman, "Open Data in Scientific Settings: From Policy to Practice," in *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16 (2016 CHI Conference on Human Factors in Computing Systems, San Jose, 2016), 1585–96, https://doi.org/10.1145/2858036.2858543.
37. National Research Council, *Preparing the Workforce for Digital Curation*; Clifford A. Lynch, "Big Data: How Do Your Data Grow?" *Nature* 455, 7209 (September 2, 2008): 28–29, https://doi.org/10.1038/455028a; Clifford A. Lynch, "Jim Gray's Fourth Paradigm and the Construction of the Scientific Record," in *The Fourth Paradigm: Data-Intensive Scientific Discovery*, ed. Anthony J. G. Hey, Stewart Tansley, and Kristin Tolle (Redmond, WA: Microsoft, 2009), 177–84; Lynch, "The Next Generation of Challenges in the Curation of Scholarly Data"; "Big Data in the Campus Landscape," *EDUCAUSE Library*, September 12, 2014, https://library.educause.edu/resources/2014/9/big-data-in-the-campus-landscape; Clifford A. Lynch, "The Need for Research Data Inventories and the Vision for SHARE," *Information Standards Quarterly* 26, 2 (Summer 2014): 29–31, http://dx.doi.org/10.3789/isqv26no2.2014.05; Lynch, "Stewardship in the 'Age of Algorithms.'"
38. Christine L. Borgman, "Knowledge Infrastructures: The Invisible Foundation of Research Data (Slides and Video)," First Conference on Research Data Infrastructure (CoRDI), Karlsruhe, Germany, September 12, 2023, https://escholarship.org/uc/item/5wc9v7cf; Directorate-General for Research and Innovation, European Commission, *EOSC Interoperability Framework: Report from the EOSC Executive Board Working Groups FAIR and Architecture* (Publications Office of the European Union, 2021), https://data.europa.eu/doi/10.2777/620649.
39. Christine L. Borgman and Philip E. Bourne, "Why It Takes a Village to Manage and Share Data," *Harvard Data Science Review* 4, 3 (July 28, 2022), https://doi.org/10.1162/99608f92.42eec111; National Academies of Sciences, *Reproducibility and Replicability in Science*, 2019, https://doi.org/10.17226/25303; National Academies of Sciences, "Changing the Culture of Data Management and Sharing A Workshop," April 28, 2021, https://www.nationalacademies.org/event/04-29-2021/changing-the-culture-of-data-management-and-sharing-a-workshop.
40. Christine L. Borgman and Paul Groth, "From Data Creator to Data Reuser: Distance Matters," *Harvard Data Science Review* 7, 2 (2025), https://doi.

org/10.1162/99608f92.35d32cfc; Mark D. Wilkinson et al., "The FAIR Guiding Principles for Scientific Data Management and Stewardship," *Scientific Data* 3 (March 15, 2016): 160018, http://dx.doi.org/10.1038/sdata.2016.18.

41. Kennedy and Lynch, "A Case for Continued Strategic Investments by Research Libraries to Advance Research and Learning"; Jacqueline Sanson, "The Experience of the Bibliothèque Nationale de France," *Bibliothek Forschung und Praxis*, September 26, 2024, https://doi.org/10.1515/bfp-2024-0049; "UNIMARC Committee," IFLA, 2024, https://www.ifla.org/g/unimarc-rg/permanent-unimarc-committee-puc/; Mirna Willer and Gordon Dunsire, eds., "Front Matter," in *Bibliographic Information Organization in the Semantic Web* (Oxford: Chandos, 2013), i–iii, https://doi.org/10.1016/B978-1-84334-731-6.50006-5; Mirna Willer and Tinka Katić, "Turning Points in the Croatian Information Environment: From the 1980s to 2023," *Bibliothek Forschung und Praxis*, September 26, 2024, https://doi.org/10.1515/bfp-2024-0037.
42. Christine L. Borgman, "User Training on Online Information Retrieval Systems," in *Encyclopedia of Library and Information Science* (New York: Marcel Dekker, 1981).
43. Lynch, "The Coming Crisis in Preserving Our Digital Cultural Heritage."
44. Borgman and Groth, "From Data Creator to Data Reuser"; Alyssa Goodman et al., "Ten Simple Rules for the Care and Feeding of Scientific Data," *PLoS Computational Biology* 10, 4 (April 24, 2014): e1003542, https://doi.org/10.1371/journal.pcbi.1003542.
45. National Research Council, *Preparing the Workforce for Digital Curation*; Eva Dobozy, "Research Skills for the Future: Research Workforce Under the Spotlight," *Journal of Research Practice* 9, 1 (September 16, 2013): http://jrp.icaap.org/index.php/jrp/article/view/382; Joanne Gard Marshall, Paul Solomon, and Susan Rathbun-Grubb, "Introduction: Workforce Issues in Library and Information Science," *Library Trends* 58, 2 (2009): 121–25, https://doi.org/10.1353/lib.0.0075; "America's Workforce Desperately Needs a Data Overhaul," *MIT Press Reader* (blog), August 9, 2024, https://thereader.mitpress.mit.edu/americas-workforce-desperately-needs-a-data-overhaul/; Commonwealth of Australia, *Research Skills for an Innovative Future: A Research Workforce Strategy to Cover the Decade to 2020 and Beyond* (Canberra, Australia: Dept. of Innovation, Industry, Science and Research, 2011), http://www.innovation.gov.au/Research/ResearchWorkforceIssues/Documents/ResearchSkillsforanInnovativeFuture.pdf; "Workforce Issues in Library and Information Science, Part 2," *Library Trends* 59, 1–2 (2010), https://www.ideals.illinois.edu/handle/2142/18717; "Workforce Issues in Library and Information Science: Special Issue," *Library Trends* 58, 2 (2009), https://www.ideals.illinois.edu/handle/2142/15350; Nicholas M. Weber, Carole L. Palmer, and Tiffany C. Chao, "Current Trends and Future Directions in Data Curation Research and Education," *Journal of Web Librarianship* 6, 4 (2012): 305–20, https://doi.org/10.1080/19322909.2012.730358.
46. Christine L. Borgman, "Libraries, Digital Libraries, and Data: 30 Years of Development in Central Europe" (keynote presentation, Theory and Practice of Digital Libraries, Ljubljana, Slovenia, September 25, 2024), https://escholarship.org/uc/item/0xv2t6z0.
47. Borgman, *From Gutenberg to the Global Information Infrastructure*; Borgman, *Scholarship in the Digital Age*; Borgman, *Big Data, Little Data, No Data*.

Appendix

Bibliography

"America's Workforce Desperately Needs a Data Overhaul." *The MIT Press Reader* (blog), August 9, 2024. https://thereader.mitpress.mit.edu/americas-workforce-desperately-needs-a-data-overhaul/.

Ashenfelder, Mike. "Digital Preservation Pioneer: Clifford Lynch." *The Signal: Digital Happenings at the Library of Congress* (blog), May 29, 2013. http://blogs.loc.gov/digitalpreservation/2013/05/digital-preservation-pioneer-clifford-lynch/?goback=%2Egde_4158855_member_245450802.

Berman, Francine, Brian Lavoie, Paul Ayris, Elizabeth Cohen, Paul Courant, Lee Dirks, Amy Friedlander, et al. "Sustainable Economics for a Digital Planet: Ensuring Long-Term Access to Digital Information." Final Report of the Blue Ribbon Task Force on Sustainable Digital Preservation and Access, February 2010. http://brtf.sdsc.edu/biblio/BRTF_Final_Report.pdf.

Borgman, Christine L. *Big Data, Little Data, No Data: Scholarship in the Networked World*. Cambridge, MA: MIT Press, 2015.

———. *From Gutenberg to the Global Information Infrastructure: Access to Information in the Networked World*. Cambridge, MA: MIT Press, 2000.

———. "Knowledge Infrastructures: The Invisible Foundation of Research Data (Slides and Video)." Presented at the First Conference on Research Data Infrastructure (CoRDI), Karlsruhe, Germany, September 12, 2023. https://escholarship.org/uc/item/5wc9v7cf.

———. "Libraries, Digital Libraries, and Data: 30 Years of Development in Central Europe." Keynote presentation at the International Conference on Theory and Practice of Digital Libraries, Ljubljana, Slovenia, September 25, 2024. https://escholarship.org/uc/item/0xv2t6z0.

———. "Library Automation at Dallas Public Library." In *Information Management in the 1980's: Proceedings of the ASIS Annual Meeting 1977 Volume 14 : 40th Annual Meeting*, Chicago, Illinois, September 26–October 1, 1977, edited by Bernard M. Fry and Clayton A. Shepherd, 14:2-A9-A-14 Microfilm. American Society for Information Science. White Plains, NY: Knowledge Industry Publications for American Society for Information Science, 1977.

———. *Research Report Prepared for OCLC on End User Behavior on the Ohio State University Libraries' On-Line Catalog: A Computer Monitoring Study*. OCLC 9891430. Dublin, OH: OCLC, 1983.

———. *Scholarship in the Digital Age: Information, Infrastructure, and the Internet*. Cambridge, MA: MIT Press, 2007.

———. "The Invisible Library: Paradox of the Global Information Infrastructure." *Library Trends* 51 (2003): 652–74. http://hdl.handle.net/2142/8487.

———. "The Premise and Promise of a Global Information Infrastructure." *First Monday* 5, 8 (August 7, 2000). https://doi.org/10.5210/fm.v5i8.784.

———. "The User's Mental Model of an Information Retrieval System: An Experiment on a Prototype Online Catalog." *International Journal of Man-Machine Studies* 24, 1 (January 1, 1986): 47–64. https://doi.org/10.1016/S0020-7373(86)80039-6.

———. "User Training on Online Information Retrieval Systems." In *Encyclopedia of Library and Information Science*, 32:259–306. New York: Marcel Dekker, 1981.

———. "What Are Digital Libraries? Competing Visions." *Information Processing & Management* 35, 3 (May 1999): 227–43. https://doi.org/10.1016/S0306-4573(98)00059-4.

———. "Why Are Online Catalogs Hard to Use? Lessons Learned from Information-Retrieval Studies." *Journal of the American Society for Information Science* 37, 6 (November 1986): 387–400. https://doi.org/10.1002/(SICI)1097-4571(198611)37:6<387::AID-ASI3>3.0.CO;2-8.

———. "Why Are Online Catalogs Still Hard to Use?" *Journal of the American Society for Information Science* 47, 7 (1996): 493–503. https://doi.org/10.1002/(SICI)1097-4571(199607)47:7<493::AID-ASI3>3.0.CO;2-P.

Borgman, Christine L., Hal Abelson, Lee Dirks, Roberta Johnson, Kenneth R. Koedinger, Marcia C. Linn, Clifford A. Lynch, et al. "Fostering Learning in the Networked World: The Cyberlearning Opportunity and Challenge. A 21st Century Agenda for the National Science Foundation. Report of the NSF Task Force on Cyberlearning." Washington, DC: Office of Cyberinfrastructure and Directorate for Education and Human Resources. National Science Foundation, June 24, 2008. https://www.nsf.gov/pubs/2008/nsf08204/nsf08204.pdf.

Borgman, Christine L., and Philip E. Bourne. "Why It Takes a Village to Manage and Share Data." *Harvard Data Science Review* 4, 3 (July 28, 2022). https://doi.org/10.1162/99608f92.42eec111.

Borgman, Christine L., and Paul Groth. "From Data Creator to Data Reuser: Distance Matters." *Harvard Data Science Review* 7, 2 (2025). https://doi.org/10.1162/99608f92.35d32cfc.

Borgman, Christine L., and Heather Hessel. "Report on the First Joint Conference on Digital Libraries." *D-Lib Magazine* 7 (2001). http://www.dlib.org/dlib/october01/borgman/10borgman.html.

Borgman, Christine L., and Neal K. Kaske. "Determining the Number of Terminals Required for an On-Line Catalog through Queueing Analysis of Catalog Traffic Data." *Clinic on Library Applications of Data Processing (17th: 1980)*, 1980. https://hdl.handle.net/2142/1110.

Brin, Sergey, and Lawrence Page. "The Anatomy of a Large-Scale Hypertextual Web Search Engine." *Computer Networks and ISDN Systems*, Proceedings of the Seventh International World Wide Web Conference, 30, 1 (April 1, 1998): 107–17. https://doi.org/10.1016/S0169-7552(98)00110-X.

Brown, Ronald H., Larry Irving, Arati Prabhakar, and Sally Katzen. "The Global Information Infrastructure: Agenda for Cooperation." National Technical Information Agency, 1995. http://www.ntia.doc.gov/reports/giiagend.html.

Buckland, Michael K. *Library Services in Theory and Context*. 2nd ed. Oxford: Pergamon, 1988.

———. *Redesigning Library Services: A Manifesto*. Chicago: American Library Association, 1992. https://hdl.handle.net/2027/mdp.39015027238693.

Committee on Future Career Opportunities and Educational Requirements for Digital Curation, Board on Research Data and Information, Policy and Global Affairs, and National Research Council. *Preparing the Workforce for Digital Curation*. Washington, DC: National Academies Press, 2015. http://www.ncbi.nlm.nih.gov/books/NBK293663/.

Commonwealth of Australia. *Research Skills for an Innovative Future: A Research Workforce Strategy to Cover the Decade to 2020 and Beyond*. Canberra, Australia: Dept. of Innovation, Industry, Science and Research, 2011. http://www.innovation.gov.au/Research/ResearchWorkforceIssues/Documents/ResearchSkillsforanInnovativeFuture.pdf.

David, Paul A. *Towards a Cyberinfrastructure for Enhanced Scientific Collaboration: Providing Its "Soft" Foundations May Be the Hardest Part*. Rev. discussion papers. Stanford, CA: Stanford Institute for Economic Policy Research, 2005. http://www-siepr.stanford.edu/papers/pdf/04-01.pdf.

Directorate-General for Research and Innovation, European Commission, European Open Science Cloud (EOSC) Executive Board, Oscar Corcho, Magnus Eriksson, Krzysztof Kurowski, Milan Ojsteršek, Christine Choirat, Mark van de Sanden, and Frederik Coppens. *EOSC Interoperability Framework: Report from the EOSC Executive Board Working Groups FAIR and Architecture*. Luxembourg: Publications Office of the European Union, 2021. https://data.europa.eu/doi/10.2777/620649.

Dobozy, Eva. "Research Skills for the Future: Research Workforce under the Spotlight." *Journal of Research Practice* 9, 1 (September 16, 2013). http://jrp.icaap.org/index.php/jrp/article/view/382.

EDUCAUSE Library. "Big Data in the Campus Landscape." September 12, 2014. https://library.educause.edu/resources/2014/9/big-data-in-the-campus-landscape.

Edwards, Paul N. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: MIT Press, 2010.

———. "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems." In *Modernity and Technology*. Cambridge, MA: MIT Press, 2003.

Fox, Edward A., and Christine L. Borgman, eds. *Proceedings of First ACM/IEEE-CS Joint Conference on Digital Libraries June 24-28, 2001: Roanoke, Virginia, USA*. New York: ACM Press, 2001. http://uclibs.org/PID/32583.

Friedlander, Amy. "Communications and Content: Radio Technologies in the U.S. Infrastructure, 1865-1976." Reston, VA: Corporation for National Research Initiatives, 2005. http://www.cnri.reston.va.us/series.html#radio.

———. "Emerging Infrastructure: The Growth of Railroads." Reston, VA: Corporation for National Research Initiatives, 1995. http://www.cnri.reston.va.us/series.html#rail.

———. "'In God We Trust': All Others Pay Cash." Reston, VA: Corporation for National Research Initiatives, 1996. http://www.cnri.reston.va.us/series.html#bank.

———. "Natural Monopoly and Universal Service: Telephones and Telegraphs in the U.S. Communications Infrastructure 1837–1940." Reston, VA: Corporation for National Research Initiatives, 1995. http://www.cnri.reston.va.us/series.html#teltel.

———. "Power and Light: Electricity in the U.S. Energy Infrastructure, 1870–1940." Reston, VA: Corporation for National Research Initiatives, 1996. http://www.cnri.reston.va.us/series.html#power.

Goodman, Alyssa, Alberto Pepe, Alexander W. Blocker, Christine L. Borgman, Kyle Cranmer, Merce Crosas, Rosanne Di Stefano, et al. "Ten Simple Rules for the Care and Feeding of Scientific Data." *PLoS Computational Biology* 10, 4 (April 24, 2014): e1003542. https://doi.org/10.1371/journal.pcbi.1003542.

Gore, Albert. "Inauguration of the First World Telecommunication Conference." Buenos Aires, Argentina, 1994. https://search.itu.int/history/HistoryDigitalCollectionDocLibrary/4.144.57.en.104.pdf.

Griffin, Stephen M. "NSF/DARPA/NASA Digital Libraries Initiative: A Program Manager's Perspective." *D-Lib Magazine* 4, July–August (1998). https://www.dlib.org/dlib/july98/07griffin.html.

Hey, Tony, Herbert Van de Sompel, Don Waters, Cliff Lynch, and Carl Lagoze. "Augmenting Interoperability across Scholarly Repositories." In *Proceedings of the 6th ACM/IEEE-CS Joint Conference on Digital Libraries*, 85. JCDL '06. New York: Association for Computing Machinery, 2006. https://doi.org/10.1145/1141753.1141768.

International Federation of Library Associations and Institutions (IFLA). "UNIMARC Committee," 2024. https://www.ifla.org/g/unimarc-rg/permanent-unimarc-committee-puc/.

Joint Information Systems Committee. "Leveraging Shared Infrastructure and Expertise to Develop Digital Projects in an Academic Department: Centre for Computing in the Humanities," April 24, 2009, 1–8.

Kennedy, Mary Lee, and Clifford A. Lynch. "A Case for Continued Strategic Investments by Research Libraries to Advance Research and Learning." *Association of Research Libraries* (blog), July 10, 2020. https://www.arl.org/news/a-case-for-continued-strategic-investments-by-research-libraries-to-advance-research-and-learning/.

Kochtanek, Thomas R., and Joseph R. Matthews. *Library Information Systems: From Library Automation to Distributed Information Access Solutions*. Westport, CT: Libraries Unlimited, 2002.

Kronenfeld, Michael, and Jennie J. Kronenfeld. "Al Gore, the Internet and the National Library of Medicine." *Circulating Now from the NLM Historical Collections*, July 2, 2020. https://circulatingnow.nlm.nih.gov/2020/07/02/al-gore-the-internet-and-the-national-library-of-medicine/.

LC21: A Digital Strategy for the Library of Congress. Washington, DC: National Academies Press, 2000. https://doi.org/10.17226/9940.

Life-Cycle Decisions for Biomedical Data: The Challenge of Forecasting Costs. Washington, DC: National Academies Press, 2020. https://doi.org/10.17226/25639.

Lynch, Clifford A. "Big Data: How Do Your Data Grow?" *Nature* 455, 7209 (September 2, 2008): 28–29. https://doi.org/10.1038/455028a.

———. "Colliding with the Real World: Heresies and Unexplored Questions about Audience, Economics, and Control of Digital Libraries." In *Digital Library Use: Social Practice in Design and Evaluation*, edited by Ann Peterson Bishop, Nancy Van House, and Barbara P. Buttenfield, 191–216. Cambridge, MA: MIT Press, 2003.

———. "Digital Collections, Digital Libraries and the Digitization of Cultural Heritage Information." *First Monday*, May 6, 2002. https://doi.org/10.5210/fm.v7i5.949.

———. "From Automation to Transformation: Forty Years of Libraries and Information Technology in Higher Education." *EDUCAUSE Review* 35, 1 (2000): 60–68.
———. "Identifiers and Their Role in Networked Information Applications." *Bulletin of the American Society for Information Science* 24, 2 (1998): 17–20. https://doi.org/10.1002/bult.80.
———. "Institutional Repositories: Essential Infrastructure for Scholarship in the Digital Age." *ARL Bimonthly Report*, February 2003, 1–7. http://www.arl.org/newsltr/226/ir.html.
———. "Jim Gray's Fourth Paradigm and the Construction of the Scientific Record." In *The Fourth Paradigm: Data-Intensive Scientific Discovery*, edited by Anthony J. G. Hey, Stewart Tansley, and Kristin Tolle, 177–84. Redmond, WA: Microsoft, 2009.
———. "Life after Graduation Day: Beyond the Academy's Digital Walls." *EDUCAUSE Review* 38 (October 2003): 12–13.
———. "Open Computation: Beyond Human Reader-Centric Views of Scholarly Literatures." In *Open Access: Key Strategic, Technical and Economic Aspects*, edited by Neil Jacobs. Oxford, UK: Chandos, 2006. http://www.cni.org/staff/cliffpubs/OpenComputation.htm.
———. "Preserving Digital Documents: Choices, Approaches, and Standards." *Law Library Journal* 96 (2004): 609–17. http://www.aallnet.org/products/pub_llj_v96n04.asp.
———. "Reaction, Response, and Realization: From the Crisis in Scholarly Communication to the Age of Networked Information." *Serials Review* 18, 1–2 (March 1992): 107–12. https://doi.org/10.1080/00987913.1992.10764063.
———. "Searching the Internet." *Scientific American* 276 (March 1997): 52–56. https://doi.org/10.1038/scientificamerican0397-52.
———. "Stewardship in the 'Age of Algorithms.'" *First Monday*, December 2, 2017. https://doi.org/10.5210/fm.v22i12.8097.
———. *The Academic Library in the Networked Information Age, Preparing Your Campus for a Networked Future*. San Francisco: Jossey-Bass, 2000.
———. "The Afterlives of Courses on the Network: Information Management Issues for Learning Management Systems." *EDUCAUSE Center for Applied Research: Research Bulletin* 2002 (November 26, 2002).
———. "The Battle to Define the Future of the Book in the Digital World." *First Monday*, June 4, 2001. https://doi.org/10.5210/fm.v6i6.864.
———. "The Coming Crisis in Preserving Our Digital Cultural Heritage." *Journal of Library Administration* 38, 3–4 (June 1, 2003): 149–61. https://doi.org/10.1300/J111v38n03_04.
———. "The Integrity of Digital Information: Mechanics and Definitional Issues." *Journal of the American Society for Information Science* 45, 10 (1994): 737–44. https://doi.org/10.1002/(SICI)1097-4571(199412)45:10<737::AID-ASI4>3.0.CO;2-8.
———. "The Need for Research Data Inventories and the Vision for SHARE." *Information Standards Quarterly* 26, 2 (Summer 2014): 29–31. http://dx.doi.org/10.3789/isqv26no2.2014.05.
———. "The Next Generation of Challenges in the Curation of Scholarly Data." In *Research Data Management: Practical Strategies for Information Professionals*, edited by Joyce M. Ray. West Lafayette, IN: Purdue University Press, 2013.
———. "The Role of Digitization in Building Electronic Collections: Economic and Programmatic Choices." *Collection Management* 22, 3–4 (May 27, 1998): 133–41. https://doi.org/10.1300/J105v22n03_12.
———. "Today & Tomorrow: What the Digital Library Really Means for Collections & Services." In *Virtually Yours: Models for Managing Electronic Resources and Services*, edited by Peggy Johnson and Bonnie MacEwan, 8, 85–97. ALCTS (Association for Library Collections and Technical Services) Papers on Library Technical Services and Collections. Chicago: American Library Association, 1999. https://www.cni.org/publications/cliffs-pubs/what-the-digital-library-really-means.
———. "When Documents Deceive: Trust and Provenance as New Factors for Information Retrieval in a Tangled Web." *Journal of the American Society for Information Science and Technology* 52, 1 (2001): 12–17. https://doi.org/10.1002/1532-2890(2000)52:1<12::AID-ASI1062>3.0.CO;2-V.
———. "Where Do We Go from Here?: The Next Decade for Digital Libraries." *D-Lib Magazine* 11, 7–8 (July 2005). https://doi.org/10.1045/july2005-lynch.

Lynch, Clifford A., and Edwin B. Brownrigg. "Library Applications of Electronic Imaging Technology." *Information Technology and Libraries* 5, 2 (1986): 100–105.

Lynch, Clifford A., and Hector Garcia-Molina. "Interoperability, Scaling, and the Digital Libraries Research Agenda." IITA (Information Infrastructure Technology and Applications) Digital Libraries Workshop, 1995. http://www-diglib.stanford.edu/diglib/pub/reports/iita-dlw/main.html.

———. "Retrospective: The 1995 Interoperability, Scaling, and the Digital Libraries Research Agenda Report." 2002. http://www.dli2.nsf.gov/dli2pi2002/program.html.

Lynch, Clifford A., and Joan K. Lippincott. "Institutional Repository Deployment in the United States as of Early 2005." *D-Lib Magazine* 11, 9 (September 2005). https://doi.org/10.1045/september2005-lynch.

Marshall, Joanne Gard, Paul Solomon, and Susan Rathbun-Grubb. "Introduction: Workforce Issues in Library and Information Science." *Library Trends* 58, 2 (2009): 121–25. https://doi.org/10.1353/lib.0.0075.

Matthews, Joseph R. *Public Access to Online Catalogs: A Planning Guide for Managers*. Weston, CT: Online Inc., 1982.

McCarn, Davis B. *Online Catalogs: Requirements, Characteristics, and Costs*. Washington, DC: Council on Library Resources, 1983.

National Academies of Sciences. "Changing the Culture of Data Management and Sharing: A Workshop," April 28, 2021. https://www.nationalacademies.org/event/04-29-2021/changing-the-culture-of-data-management-and-sharing-a-workshop.

———. *Reproducibility and Replicability in Science*, 2019. https://doi.org/10.17226/25303.

National Science Foundation. "Digital Libraries," 1999. https://www.nsf.gov/news/news_summ.jsp?cntn_id=103048.

Pasquetto, Irene V., Ashley E. Sands, Peter T. Darch, and Christine L. Borgman. "Open Data in Scientific Settings: From Policy to Practice." In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 1585–96. CHI '16. San Jose, CA, 2016. https://doi.org/10.1145/2858036.2858543.

Research Libraries Group. "Public Online Catalogs and Research Libraries: Final Report to the Council on Library Resources." Stanford, CA, 1982.

Ribes, David, and Thomas Finholt. "The Long Now of Technology Infrastructure: Articulating Tensions in Development." *Journal of the Association for Information Systems* 10, no. 5 (May 28, 2009). https://doi.org/10.17705/1jais.00199.

Ribes, David, and Charlotte P. Lee. "Sociotechnical Studies of Cyberinfrastructure and E-Research: Current Themes and Future Trajectories." *Computer Supported Cooperative Work (CSCW)* 19, 3 (August 1, 2010): 231–44. https://doi.org/10.1007/s10606-010-9120-0.

Sanson, Jacqueline. "The Experience of the Bibliothèque Nationale de France." *Bibliothek Forschung und Praxis*, September 26, 2024. https://doi.org/10.1515/bfp-2024-0049.

Star, Susan Leigh, and Karen Ruhleder. "Steps Toward an Ecology of Infrastructure: Design and Access for Large Information Spaces." *Information Systems Research* 7, 1 (March 1996): 111–34. https://doi.org/10.1287/isre.7.1.111.

Tyner, Sue, and Clifford A. Lynch. "University of California Union Catalog: An Overview of Bibliographic Issues." In *Communicating Information: Proceedings of the 43rd ASIS Annual Meeting*, edited by A. R. Benenfeld and Edward J. Kazlauskas, 266–69. Anaheim, CA, 1980.

Wagner, R. Polk. "Information Wants to Be Free: Intellectual Property and the Mythologies of Control." *Columbia Law Review*, January 1, 2003. https://scholarship.law.upenn.edu/faculty_scholarship/742.

Weber, Nicholas M., Carole L. Palmer, and Tiffany C. Chao. "Current Trends and Future Directions in Data Curation Research and Education." *Journal of Web Librarianship* 6, 4 (2012): 305–20. https://doi.org/10.1080/19322909.2012.730358.

Wilkinson, Mark D., Michel Dumontier, IJsbrand Jan Aalbersberg, Gabrielle Appleton, Myles Axton, Arie Baak, Niklas Blomberg, et al. "The FAIR Guiding Principles for Scientific Data Management and Stewardship." *Scientific Data* 3 (March 15, 2016): 160018. http://dx.doi.org/10.1038/sdata.2016.18.

Willer, Mirna, and Gordon Dunsire, eds. "Front Matter." In *Bibliographic Information Organization in the Semantic Web*, i–iii. Oxford, UK: Chandos, 2013. https://doi.org/10.1016/B978-1-84334-731-6.50006-5.

Willer, Mirna, and Tinka Katić. "Turning Points in the Croatian Information Environment: From the 1980s to 2023." *Bibliothek Forschung und Praxis*, September 26, 2024. https://doi.org/10.1515/bfp-2024-0037.

"Workforce Issues in Library and Information Science, Part 2." *Library Trends* 59, 1–2 (2010). https://www.ideals.illinois.edu/handle/2142/18717.

"Workforce Issues in Library and Information Science: Special Issue." *Library Trends* 58, 2 (2009). https://www.ideals.illinois.edu/handle/2142/15350.