Information Revolutions, the Information Society, and the Future of the History of Information Science

W. Boyd Rayward

Abstract

This paper aims to discuss the future of information history by interrogating its past. It presents in outline an account of the conditions and the trajectory of events that have culminated in today's "information revolution" and "information society." It suggests that we have already passed through at least two information orders or revolutions as we transition, first, from the long era of print that began over five hundred years ago with Gutenberg and the printing press. We have then moved through a predigital era after World War II, finally to a new era characterized by the advent of the ubiquitous technologies that are considered to herald a new "digital revolution" and the creation of new kind of "information society." It argues that it is possible to see that the past is now opening itself to new kinds of scrutiny as a result of the apparently transformative changes that are currently taking place. It suggests that the future of the history of information science is best thought of as part of a still unrealized convergence of diverse historical approaches to understanding how societies are constituted, sustained, reproduced, and changed in part by information and the infrastructures that emerge to manage information access and use. In conclusion it suggests that different bodies of historical knowledge and historical research methodologies have emerged as we move into the digital world that might be usefully brought together in the future to broaden and deepen explorations of important historical information phenomena from Gutenberg to Google.

Five hundred years ago, Gutenberg was responsible for initiating an information and communications revolution. Historically, it had profound epistemic, social, economic, and political consequences.[1] I suggest that in

LIBRARY TRENDS, Vol. 62, No. 3, 2014 ("Essays in Honor of W. Boyd Rayward: Part 2," edited by Alistair Black and Charles van den Heuvel), pp. 681–713.

the modern era, this is the first of what are essentially three information revolutions, or revolutionary periods, that we have passed through. In this I am following Headrick for whom the Information Age has no beginning, being as "old as humankind." But he suggests that "in the course of history there have been periods of sharp acceleration (revolutions, if you prefer) in the amount of information that people had access to and in the creation of information systems to deal with it" (Headrick, 2000, p. 8).[2]

For my purposes the first information revolution, or information order, is print based. It is characterized by the emergence of complex, interlinked institutional information and communications infrastructures that were both a response to and provided support for the industrial, democratic, and nationalist developments that have in a period of five hundred years transformed Western societies. (I make clear the limitation that my focus is on Western industrialized nations.)

The second revolution or information order is dominated by predigital developments that, though still essentially print based, begin in my view with the advent of World War II and involve attempts to deal with an emerging sense of crisis in the production and management of information, especially scientific and technical information, in the ensuing thirty or so years.

The third information revolution or order, I suggest, begins in the 1990s with the advent of the online world of digitization, the Internet, and the World Wide Web and their now ubiquitous information systems and technologies that are currently transforming our lives. I hasten to stress that I am not arguing of these information orders or revolutions that one supersedes the next. Rather, each builds on what went before, sits on but also reconfigures a continuing, underlying arrangement of functions, systems, and structures whose origins can be traced, at least for my purposes, back to Gutenberg.

The Gutenberg Information Revolution

Formal recorded information in the long period of Gutenberg's world of print has typically been considered to be expressed in, and transmitted by, documents, especially books, journals, and a range of other printed and manuscript sources. Organizational structures and social practices were necessary to create and manage the relevant technologies and to institute the legal and commercial frameworks that were required for the production, regulation, and dissemination of these information sources. An ever-expanding range of users began to draw on them for an increasingly complex range of religious, political, social, research, educational, and recreational purposes. Of central importance in understanding the emergence of the Gutenberg-based information and communications infrastructures and what these infrastructures supported was the fact that they were an integral part of the general secularization, modernization, and industrialization of Western capitalist economies. They functioned in a variety of market places within which the typical market forces of supply, demand, and product and technological innovation were at play.

These infrastructures have functioned at several levels. One that we sometimes neglect to take into account historically is the level of basic "affordances." At this level, for example, are phenomena that range from the economic and technical conditions that are needed for the manufacture of pens, paper, and inks, commercial glues, and sewing machines, to the foundry practices involved in casting type, to the development of printing presses, typewriters, and photocopiers. Among these affordances are communication systems and networks that have facilitated the movement of goods, people, and mail by road, rail, shipping, and ultimately air. Some of these phenomena are discussed, for example, by Daniel Headrick in his book *Tools of Empire,* in a section he called "The Communications Revolution," though he was dealing with the nineteenth century (1981, pp. 127–213). Other information and communications technologies such as the telegraph (designated the "Victorian Internet" by Tom Standage, 1998) and telephone systems and later still radio and television were all aspects of this emerging and diversifying communications and information infrastructure that helped amplify and added to what was available in print. They provided what Paul Otlet was to call "substitutes for the book," which he began to discuss as early as 1906 (Otlet, 1906, pp. 31–34; also 1934, section 234).

Developments, that is to say, in the Gutenburg world of print rested on developments in the capitalist economies of Europe and its dependencies. The management of information—the identification, recording, and manipulation of data about products and markets—has had a particular salience in the historical development not only of Western economies but of the larger societies of which they are part. Office technologies and the systems that they helped constitute had to respond to the expansionary and competitive requirements of firms whose commercial webs gradually spread nationally, regionally, and as the nineteenth century especially progressed, eventually globally. Governments were no less expansionary. On the one hand in competition with one another, they built their colonial empires and the alliances and armaments that asserted their nationalist identities and aspirations. But on the other, they were also increasingly engaged in managing issues of national social and economic policy. Information, defined as textual, graphical, or statistical, delivered in print or by telegraph or other communications media, was everywhere grist to the administrative mill whether commercial or governmental (Chandler, 1977; Chandler & Cortada, 2000; Povey, 1998; Gardey, 2008).

Beyond this fundamental level of infrastructure are the developments that are directly concerned with the recording, production, dissemination, management, and use of information and information services.

These are the organizational, technological, social, economic, and political arrangements that supported the Gutenberg world of print as it eventually permeated every aspect of people's lives—as indeed it still does to some extent today. Here we find in overlapping sets of relationships the development of the publishing and communications industries in all their emergent complexity of technologies, legislative and regulative frameworks, and social practices. These enable the production and distribution of the enormously diversified range of formats in which information is expressed and delivered in the service of an almost infinitely varied range of purposes—books in all their variety from pop-up books for children, to coffee-table books, to treatises of fearsome erudition in several languages, ancient and modern, to multivolume encyclopedias, for example. But the range of journals and periodicals, newspapers, bibliographies of various kinds, indexing and abstracting services, data compilations . . . is no less varied. Here too are the developments that have led to the emergence and proliferation of reading populations, of learned and professional societies, universities and research organizations, and schools and of course, museums, archives, and libraries for all of which the Book—the "Document" or "Livre-Document" in the enlarged Otletian sense (Otlet, 1903, 1907)—is a central resource to be variously produced, consumed, collected, and preserved.

The infrastructural arrangements of the print world functioned and still function at local, national, and international levels. Each level has its own particular organizational structures, overlapping memberships, and codes of standards and practices. In these arrangements we find the still largely paper-based bureaucracies by means of which governments, commercial establishments, and other national and international organizations ensure identity, continuity, adaptability, and administrative effectiveness.

Developments before World War I: An information infrastructure apotheosis

The decades at the end of the nineteenth century and before World War I were a period of the efflorescence of great competitive empires and of the development of what the Scottish sociologist and urbanist, Patrick Geddes, was one of the first to call "a new industrial age, a second Industrial Revolution" (1915, p. 46). It was a period in which social and technical developments in the production, consumption, and management of print reached a kind of crescendo of effort and experimentation that resulted in what we now consider to have been extraordinarily grandiose projects, given the technology of their times. Most of the domains of knowledge had been named and formalized in structures consisting of academies and national and international associations and societies. These met regularly, in the case of international meetings often on the occasion of the World's Fairs that were such a feature of the period, and most published proceedings of their meetings. They also published journals, handbooks, indexing and abstracting services, and annual reviews in increasing numbers. Most of this production of print was eventually captured in the states of the Western world by comprehensive national systems of bibliography, both official and trade (e.g., Growoll, 1903; Linder, 1959).

It seemed all too evident that accelerating growth, increasing diversification, dispersive fragmentation, and rapid internationalization characterized the world of knowledge in this period when Gutenberg's technology of print seemed to reach its zenith. The enormous information infrastructural projects of the time were designed to offset the problems that these developments had brought in their wake. To give an example of the thinking that lay behind such projects, one might begin as early as 1856 with Andrea Crestadoro's speculations about how to publish—and so extend the reach of—the British Museum Library's catalogue, the publication of which had recently been discussed. He declared that if the procedures proposed by him were to be followed,

> if the museum were burnt to the ground, its inventory and its Index would lose not one iota of their colossal usefulness; but on the contrary they would continue to be an example of well-spent money, not only for the service of the British nation but as aid in the progress of civilization all over the world. . . . The whole world would thus be converted into a single library, as it were; all its intellectual contents inventoried; all those inventories incorporated into one Universal Index. (1856, pp. 53, 59)

Despite these early discussions, the actual publication of the catalogue was not undertaken until some thirty years later (McCrimmon, 1981).

Here are a few highly selected examples of these extraordinarily ambitious information infrastructural projects of the period, some of which would not be completed until after the World War II and then, later, would also be translated into digital formats:

> *The British Museum Catalogue of Printed Books* (1888–1900), 98 volumes (13 volume supplement, 1905).
>
> Bibliothèque Nationale, *Catalogue Général, Auteurs* (1897–1981), 232 volumes.
>
> Institut International de Bibliographie, Brussels, *Répertoire Bibliographique Universel, N* (*Noms*): 4,989,600 entries by 1912 (Masure, 1913, p. 18); 16,000,000 by 1934 (Otlet 1934, 405).
>
> Royal Society of London, *Catalogue of Scientific Papers, 1800–1900* (1867–1925), 19 volumes.
>
> *International Catalogue of Scientific Literature, 1901–1914* (Published under the auspices of the Royal Society of London, 1902–1921), 254 volumes.
>
> *Concilium Bilbiographicum*, Zurich; total of the cards issued to subscribers of the sets of cards for zoology, anatomy, physiology, microscopy, biology, and paleontology, 1895– 1910: 30,857,500 (Concilium Bibliographicum, 1910, p. 26).
>
> Société mathématique de France, *Répertoire bibliographique des sciences mathématiques* (1894–1912), 20,000 cards.

> J. C. Houzeau & A. Lanscaster, *Biblographie générale d'astronomie ou catalogue méthodique des ouvrages, des mémoires ou des observations astronomiques publiés depuis l'origine de l'imprimerie jusqu'en 1889* (Bruxelles: Hayez, 1882–1889), 2 volumes (volume 1 published in 2 parts) (revised edition, ca. 2850 pages). This bibliography was designed to provide a complete record of "all that had been written about the science of the heavens since the beginning of history." (Dewhirst, 1964, p. xiv)

Another astronomy project typical of the period was the Carte du Ciel, which "aimed at preparing a photographic chart of the whole heavens showing stars to the fourteenth magnitude and a catalogue giving precise positions for all stars to the eleventh magnitude—that is for over two million stars" (Gill, 2008, p. 305). This began with a large international congress in Paris in 1887 and involved the collaboration of nineteen observatories throughout the world that agreed to use standard observational and photographic equipment and methods. The project and the publication of the accompanying *Astrographical Catalogue* were not completed until 1964 and involved notable developments in photography (Aubin, 2003, p. 99).

For standard data and technical constants, the *Physikalisch-chemische Tabellen*, of H. Landolt und Richard Börnstein, was first published in 1883 in a small volume of 249 pages. By the time of its fourth edition in 1912, it had become a volume of 1313 pages. Its fifth edition appeared in 2 volumes in 1923 with five supplementary volumes through 1936.

In 1912 the Congress of Applied Chemistry, under the auspices of the International Association of Academies, began to issue *Tables Annuelles de constants et données numériques de chimie, de physique et de technologie*. This, covering publications from 1910 to 1934, appeared in twelve volumes with two index volumes through 1937. The International Critical Tables based on material in the *Tables Annuelles* was published in seven volumes in the period 1926–1933.

To take a quite different example, perhaps the most famous general English encyclopedia, the *Encyclopedia Britannica*, appeared in three volumes at the end of the eighteenth century. Its famous eleventh edition of 1911 consisted of twenty-nine volumes with contributions from some of the most important scholars and literary figures of the day.

Post World War I: Challenges to the old information order

After World War I, many of the great nineteenth-century information infrastructural projects mentioned above stagnated or were discontinued. *The International Catalogue of Scientific Literature*, for example, was not resumed after the war. The *Répertoire Bibliographique Universel* of the International Institute of Bibliography became inaccessible after 1934 when the Belgian Government ceased to support the organization and closed its location in Brussels in what was known as the Palais Mondial. The Concilium Bibliograhicum never fully recovered from the death of its founder, Herbert Haviland Field, in 1921 (Ward, 1921), though it limped along for a period with the support of the U.S. National Academy of Science and the Rockefeller Foundation and fell silent only with the death of Field's successor, Johannes Strohl, in 1942. Projects like these, perhaps because of their monumental scale, were inevitably inadequately supported; their preparation was quickly outmoded technologically; and they were so slow to appear and cumbersome to use that they were unable effectively to meet the changing needs of scientists and others for whom they were intended.

But the information infrastructural problem after World War I was more general. Malclès, for example, observed that "almost all the bibliographies covering large subject areas or long periods of time were immobilized after 1914." She also suggested that "the specialized bibliographies which had been part of periodicals or had an independent existence supported by scholarly organizations since the end of the 19th century passed through the same period of atrophy which had affected retrospective bibliography after 1914." It was, she believed, a period that saw the "constantly accelerating passing of the old [bibliographic] order." But in her view, the decline was offset after the 1930s by "the creation and development in most countries almost overnight of documentation centers which enjoyed a bright future." These were, in effect, a new kind of information infrastructural arrangement that had been discussed in the period before the war by Paul Otlet (Malclès, 1989, pp. 104–6; Rayward, 1997, p. 294).

Malclès does not attempt to explain the reasons for what she believed was happening, but some of them are perhaps obvious. Before the war, according to Schroeder-Gudehus, Germany had produced about 45 percent of world production of scientific periodicals. She quotes J. D. Bernal's observation that German had become "pre-eminently the international language of science and [that] German professors [had] set up a kind of scientific Empire which covered all northern, central, and eastern Europe and exerted considerable influence on the science of Russia, the United States and Japan." She also quotes a complaint to the editor of the journal *Nature* against "the numberless *Archiv, Jahrbücher, Zeitschriften, Zentralblatter* and so on . . . [that] have gradually monopolized the whole of scientific production of the world. . . . Thus were apparently built up international scientific organs, but in reality German instruments of control and monopoly of science" (Schroeder-Gudehus, 1973, p. 99). These ventures became postwar victims not only of changed economic circumstances but of a general revulsion even in scientific circles from things German.

Nevertheless there were important information infrastructural developments in the brief interwar period that deserve to be noted. One is the creation in 1919 of the International Research Council and the International Academic Union. These organizations were set up essentially by

Allied scientific and scholarly interests to replace the German-dominated International Association of Academies created in 1899 (Alter, 1980). Membership of representatives from the Central Powers in the International Research Council and its Unions was forbidden by the Council's statutes, and even neutral powers could be admitted only on the basis of a three-quarters majority (Cock, 1983, p. 249). One of the functions, then, of these new organizations was in effect to restrict communication and the flow of information internationally—that is, to enforce a "boycott" of the work of scientists and scholars from the Central Powers, though there were those who resisted this punitive approach to the defeated enemy (Cock, 1983). Schroeder-Gudehus gives the startling statistic that of 275 international congresses "held between 1919 and 1925 in the entire field of the humanities, natural and technical sciences, sixty percent met without the participation of a German delegation" (1973, p. 98). She concludes that even though the boycott was never fully effective "in comparison to the pre-war situation, there was no possible doubt that the official moral banishment of German science from the international co-coordinating organizations and their activities seriously affected the development of normal international collaboration in the scientific domain" (p. 102). In 1926 German membership in the Unions and Council was allowed, and in 1931 the Council was reorganized to create the International Council of Scientific Unions. This institutionalized an interest in issues of the management of scientific literature by creating in conjunction with UNESCO an Abstracting Board in 1952, which transitioned into the International Council for Scientific and Technical Information (ICSTI) in 1984 (Greenaway, 1996).

In these first years of the International Research Council, Paul Otlet hoped to help give it a strong information-based focus. He submitted a proposal to the first meeting of the Council that an International Union for Bibliography and Documentation be created along with the other international scientific Unions whose creation was then being foreshadowed. He reported that this idea had been accepted in principle (Rayward, 1975, p. 209). While his view was universalist, a proposal was also made that the Council create an Interallied Office of Scientific Documentation to issue reviewing journals in a range of scientific subjects to replace those that had previously originated in Germany (Richards, 1994, p. 7). Bernal observed that "it was not so much that German scientists were in the front rank of discovery, but that Germany had taken on the task of the systematization and codification of all science, so that the record of the progress of human knowledge was largely in German hands" (Richards, 1994, pp. 74–5). An interesting reflection of the basis for this kind of anxiety is statistics on abstracting services in this period. Even after the war, in 1920 the number still being published in Germany (sixty-six) was higher than the number in any one of the UK, the United States, or France, though added together the number in these countries was of course larger (Manzer, 1977, pp. 111, 164, 183). Schroeder-Gudehus notes that while 40 percent of the production of chemical literature before the war was in German, in 1929 it was still 27 percent (1973, p. 99).

While nothing came of these proposals for the International Research Council to play an extended information role with respect to scientific documentation, the conferences of the organization that had begun life in 1895 as the International Institute of Bibliography, of which Otlet was a moving force, were continued after the war with ever-larger attendance as their scope broadened. In 1931, to reflect its changing focus, the Institute changed its name to The International Institute for Documentation; and later, in 1937, to the International Federation of Documentation (FID). In 1926, what was to become the International Federation of Library Associations (IFLA) was formed, and in Rome in 1928 held the first of its annual conferences that have since then continued regularly in different cities throughout the world. Its programs have had a major impact on the international standardization and sharing of bibliographic data.

But perhaps most iconic of all of the international institutional arrangements concerned with the management of information in this interwar period was what H. G. Wells described as "the organization of a sufficient instrument by which war may be ended for ever" (Wells, 1918, p. vii). This was the League of Nations. The League created an International Committee of Intellectual Cooperation in 1922 with a subcommittee on bibliography, and later, in Paris, an International Institute for Intellectual Cooperation, the forerunner of the modern UNESCO (Renoliet, 1999). Both the Committee and the Institute were concerned with scientific information, the nature and role of documentation, and the work of museums, archives, and libraries.

There was a range of important organizational developments nationally in this period too, though a comprehensive account is not attempted here. In England, for example, the Association of Special Libraries and Information Bureaux (ASLIB), created in 1924, sought to bring together interests represented by what Otlet before the war and Malclès after it had called documentation centers. In France l'Union Française des Organismes de Documentation (UFOD) was created in 1931 with a similar purpose to that of ASLIB. In the United States the now powerful Association for Research Libraries was formed in 1932 in Chicago. In 1937 Watson Davis and his colleagues founded the American Documentation Institute (ADI) in Washington D.C., actively modelling its interests on those of the FID.

Then came the Depression. International scholarly congresses continued to meet; journals, indexes, and abstracting services and so on struggled to continue to be published under the difficult conditions of the time. One—perhaps signature—"information" event of this pre–World War II period was the sponsorship by the League of Nation's International Institute for Intellectual Cooperation of a great World Congress on Universal Documentation on the occasion of the World's Fair in Paris in 1937. As Buckland notes: "The literature on documentation in the 1930s was as preoccupied with microfilm technology as it is now with computer technology and, for the same reason, each being the most promising information retrieval technology of the time" (1992, p. 290; see also Binkley, 1936). It is not surprising then that one of the features of this enormous meeting was an American exhibit of the actual production onsite of microfilm copies of two hundred thousand pages of *le journal des debats* and *le Temps* (Rayward, 1983, p. 258). The project was designed to demonstrate the commercial and professional feasibility of the current state of micrographic technology for this kind of high-volume copying, though the use of microfilm for such purposes had first been demonstrated by Paul Otlet and Robert Goldschmidt as early as 1906 (Otlet and Goldschmidt, 1906). Microfilm was to become enormously important during and immediately after the War for the acquisition and reproduction of documents.

World War II, Scientific Information, and the Predigital Information Age

I argue that it is after World War II that an increasingly intense and complex interweaving of discourse, experimentation, and invention related to the management of information began to develop and accelerate. If for Malclès (1989) the interwar years saw "the constantly accelerating passing of the old order" (p. 105), the postwar period could be described as witnessing an accelerating new information order. It saw the emergence of changes so extensive and rapid that I argue a new information revolution can be seen as getting underway. Scott Adams observed that the war had encouraged "the greatest explosion of bibliographic activity the world has ever known" (cited in Farkas-Conn, 1990, p. 110). The new postwar "information order" involved a heterogeneous group of librarians, scientists, engineers, government officials, industrial researchers of various kinds, and commercial entrepreneurs who were responsible for introducing innovative systems, technologies, and new organizational arrangements for the management of information.

The requirements for information of the Allied Powers as part of their war effort had been an important stimulus for the processes of change. One might mention here the Office of Scientific Research and Development created by the U.S. Government. Among other things its goal was "to reduce the time lag between the completion of war related research and the implementation of the necessary procurement programs;" but it also became a major agency for Allied research cooperation during the war (Farkas-Conn, 1990, pp. 100–101). Also fundamental to the war effort was the U.S. Office of Strategic Services. This provided a site for introducing, developing, and testing new mechanisms for examining and utilizing information. Irene Farkas-Conn (1990) has described how "teams of engineers would evaluate enemy information from occupied territories, prepare digests of the captured documents, and review them with Allied intelligence officers" (p. 103). Peiss at the University of Pennsylvania is working on what she calls the "microfilm men" who during the war, as part of the Interdepartmental Committee for the Acquisition of Foreign Publications (IDC or Indec), located and microfilmed huge quantities of documents in the neutral countries for use of various Allied war agencies in Washington and London (2007).[3] Eugene Powers, for example, founder of University Microfilms, was in charge of an operation in Stockholm in which mailbags from Germany were intercepted and their contents of newspapers, serials, and scientific journals microfilmed. Between 1942 and 1945, it has been claimed that five million pages were copied and sent to Washington (Farkas-Conn, 1990, p. 103).

The information aftermath of World War II

As the war drew to a close, the focus of collecting activity in Europe gradually changed from finding militarily useful information to finding and filming documents useful to industry and medicine as well as to the military. One estimate puts the "total take" of documents collected in 1945 by the U.S. Field Information Agency, Technical (FIAT), at 3.5 billion microfilmed pages (Varlejs, 2004, p. 90). Irene Farkas-Conn (1990) has described many of the developments of the time in detail in her aptly named chapter "The War Years, then Information Turmoil." In six months in 1945, for example, the Air Documents Research Center alone had accumulated 186 tons of enemy documents (p. 103). In 1945, Vannevar Bush, who headed the U.S. Office of Research and Development that was slated for abolition at the end of the war, declared that, except for what was nationally sensitive, all of the voluminous information it had collected should be declassified and made accessible as quickly as possible. Varlejs (2004) has described the work of the Office of Technical Services, set up in 1946 to organize and distribute the mass of technical reports that had become available after the war.

Similarly, in 1946, with the establishment of the U.S. Atomic Energy Agency, much of the documentation of the Manhattan project was declassified and had to be indexed and abstracted. Beginning this work in 1946, the Oak Ridge Technical Information Center began to publish *Nuclear Science Abstracts* in 1948. *Nuclear Science Abstracts* undertook the world coverage of all multidisciplinary, multiformat materials concerned with the peaceful uses of nuclear energy. The volume of this material—already vast—increased rapidly after 1955 and 1958 when the UN-sponsored conferences on the peaceful uses of nuclear energy led many countries to release hitherto classified information. Eventually, in a move from the national to the international (one of many in the area of secondary information services), in 1976 *Nuclear Science Abstracts* was merged into the International Nuclear Information System (INIS) of the International Atomic Energy Agency (Vaden, 1992; Woolston, 2004).

What is new in all of this is that enemy documents and the hitherto classified information in Allied research reports were perceived to be of vital and immediate importance; that the information in the reports aged quickly; and that traditional bibliographical and library-based methods of organizing and providing access to the contents of these reports were too slow and not fine-grained enough. It was also understood that dealing with this material was not merely suitable work for scientists, engineers, and others with substantive knowledge and technical know-how, but required such personnel (something to be reinforced later by the famous Weinberg Report of 1963). Indeed it became clear that after the war there would be no return, in the United States certainly, to the bibliographic *status quo ante*. According to Eugene Scott, Executive Secretary to the Interdepartmental Committee on Scientific Research and Development writing in 1953, in 1930 national research expenditure was $130 million; in 1952 it was $2.9 billion. In 1930 there were 1600 industrial research laboratories; in 1952 more than 3,300 (Scott, 1953). Such figures help explain the increasing volume and complexity of the research literature that had to be managed in a relatively brief time. The advent of Sputnik in 1957 and the massive expansion of research and development in the United States that followed simply added to the dimensions of a problem that was already being regarded as becoming unmanageable.

The paragraphs above have dealt with scientific and technical literature in the immediate postwar period and the pressures that this literature placed on techniques for storage and access. But similar issues arose, as Robert B. Downs has observed, in relation to reference and research libraries:

> In the first and second World Wars, the European book market was almost completely cut off from American libraries. Nearly all the normal channels of communication, transportation, and trade were closed; materials were destroyed or confiscated in transit; and little information was available on the nature and extent of publishing in the countries at war. In each period the curtain descended further for American libraries when the United States became an active belligerent. (1949, p. 157).

In the case of the Second World War, in 1945 the Library of Congress added to its wartime acquisitions programs by creating the Library of Congress Post War Mission to Europe. This was a successor to the wartime Interdepartmental Committee for the Acquisition of Foreign Publications

(IDC) mentioned above. It was carried out by twenty-six librarians and documentalists who were sent to various places in Europe

> to purchase publications of the war years, to screen and ship materials obtained from German army and Nazi party sources, and to locate and evacuate stocks of books held by German dealers for American libraries. Members of the mission were directed to procure up to fifty copies of books of general reference value and at least three copies of all other publications. In addition to these materials, the Library of Congress made available for distribution large quantities of duplicate foreign publications received from the Office of Censorship, Army Military Intelligence, the Historical Records Branch of the Army, and other sources. Included were Italian, French, Swiss, Dutch, Belgian, German, and Austrian titles. (Downs, 1949, p. 159).

While the program was officially in place for only three years, 819,022 books and periodical volumes were acquired, representing approximately two million pieces for distribution to the participating libraries. The program was essentially replaced by the Farmington Plan for the acquisitions of foreign materials for United States research libraries. Initial discussions about this also took place during the war, but it became fully active only in 1948. The central idea behind the plan was that a least one copy of every publication of research value in the world would find its way into one of the cooperating United States's libraries. There is an extensive amount of literature on the Farmington Plan, a project initiated by a grant from the Carnegie Corporation of New York and supported for a time by grants from the Council of Library Resources. Its early history is outlined in great detail in Williams (1953). It was discontinued in 1972 because of costs, organizational issues, language problems, and the marginal nature of much of the material acquired (George & Blixrud, 2002, p. 13).

"Nonconventional" technical information systems

For a period of nearly thirty years after the war, before the maturing of computer technology, most of the new approaches to system development involved microfilm, aperture cards, various kind of punched cards, edge-notched cards, and so on (Williams, 2002b; Griffiths & King, 2002; Henderson, 1999; Casey & Perry, 1951). Indeed it was at the very opening of the period under review that in 1945, though his thinking about the issues involved began before the war, Vannevar Bush published an account of the Memex, an iconic version of what we would now call a scholar's workstation. Nevertheless, it belonged firmly to the predigital era in that its recording, retrieval, and display mechanisms were based on automatically microfilming documents and searching the microfilm in new ways (Bush, 1991 [1945]; Buckland, 1992). The Memex was the basis for an attempted realization by Ralph Shaw of a simplified version for literature searching that he called the Rapid Selector (Garfield, 1997–1978; Burke, 1992). The

Memex was conceptually more integrated and perhaps more nearly practical (though even Shaw's simplification in the form of the Rapid Selector eventually came to nothing) than Paul Otlet's multimedia work desk, the Mundothèque. But the Mundothèque rates a mention in that it encapsulates a recognition of the complexity of the multimedia formats in which information was now being produced and the technological problems of access that they posed. A rather Heath Robinsonesque construction, the Mundothèque was intended to provide multimedia access among other things to a novel, visual form of universal encyclopedia, and to be a node in a universal network for information and documentation. Otlet had argued in the late-1920s and 1930s that these had become new and necessary infrastructural developments for the international transfer of information (Otlet, 1934; Rayward, 1997; Heuvel & Rayward, 2011).

Because of the limited storage and other technological inadequacies of the equipment, in order to operate efficiently the system innovations of the time (early computer applications included) had to develop complex systems of codes for document identification, description, and for specifying subject content (classifications). Mathematical representation and analysis of document surrogates (such as indexing terms or descriptors) became the basis for system evaluation, simulation, and experimental research to determine optimal system configuration and capacity. An important development was the attempt, beginning in the late 1950s with the Cranfield Experiments, to find some rigorous scientific way of establishing the relative effectiveness of existing information retrieval systems and techniques (Cleverdon, 1960; Cleverdon, Mills, & Keen, 1966). These approaches helped to create what rapidly became known as information science.

In the period 1958–1966, the "nonconventional technical information systems in current use" identified by the National Science Foundation's Office of Science Information Services increased from 30 to 178. They were described as nonconventional because they were "systems . . . embodying new principles for the organization of subject matter or employing automatic equipment for storage and search" (Henderson, 1999, pp. 170, 176). They were often devised for and introduced into special information centers (the emergent documentation or information centers, mentioned above) that Otlet and Malclès had argued had become a necessary component of the infrastructures needed for the management of specialist literatures. As early as 1955, Eugene Garfield and Robert Hayne were calling on the American Association for the Advancement of Science to take the lead in creating a National Intelligence and Documentation Center that would help coordinate "the segmentalized scientific disciplines by issuance of comprehensive indexes, encyclopedias, handbooks, reviews, and other instruments that will erase the artificial boundaries of specialization" (Garfield & Hayne, 1955). The 1963 U.S. Weinberg Report

Science, Government, and Information (President's Science Advisory Committee, 1963) found, for example, that scientists were "being snowed under by a mound of undigested reports, papers, meetings, and books" and that "scientists needed help in finding the buried gems." The solution was to recommend the creation of special information centers staffed by subject specialists. The U.S. Office of Scientific and Technical Information (2000) reported that nationally more than three hundred science information centers had been created to manage the scientific "information revolution." The report also observed on the basis of the developments in computer networking that "now it is possible to link to information centers for access by scientists anytime, anywhere."

An important part of this new postwar information order was the secondary information services of indexes and abstracts, many with substantial histories behind them already. They had now to adjust to the changed conditions in part created by the war and later by Cold War issues epitomized by Sputnik, including the increasingly pressing needs of an ever-growing number of users. I am referring, for example, to *Chemical Abstracts, Physics Abstracts, Engineering Index,* and *Biological Abstracts* (which in a curious sense arose in the late 1920s on the ashes of Herbert Haviland Field's *Concilium Bibliographicum,* established in Zurich in 1895) and so on. They had to deal with the increasing volume and complexity of the journal, technical report, and other literatures from a variety of international sources. But they had also to keep production both comprehensive and current. As a result they had to develop new processes, products, methodologies, and international relationships. It was in these services that many important pioneers in information science worked on new systems, exploited new technologies, and in general sought to think about information needs and uses, especially in the sciences, in new ways. One of the most important of these figures was a young Eugene Garfield, who created an innovative approach to indexing that involved what he called "the association of ideas." Proposed in the mid-1950s and implemented in the early 1960s, Garfield's Science Citation Indexes provided new and rapidly indispensable modes of access to the literature of science and new tools for analyzing intellectual or disciplinary relationships and research productivity (Garfield, 1955; Wouters, 1999; Yancey, 2005).

Information searching behavior and new information milieux

It gradually became clear in this period that information needs, access, and use were complexly interconnected behavioral phenomena, that information behavior was no less a subject for definition and investigation than any other aspect of human behavior, and no less difficult to carry out. Information systems and their technologies were embedded in intricate systems of social relationships and the shared practices of scholarly and other communities. If an adequate solution to the problems of managing access to information were to be found, it was necessary to understand what information was needed and by whom; how it was produced and its production financed; and how it was sought and used. Since World War II, a huge literature has emerged dealing with changing patterns of formal and informal communication among scientists and others; the social dynamics within various communities of information producers and users that affect their information behavior; and the impacts on these communities of various emergent or experimental systems of information access and exchange (see, e.g., Royal Society, 1948; Menzel, 1960; Garvey & Griffith, 1964; Ziman, 1969; Garvey et al., 1972; Lievrouw & Carley, 1990; Hurd, 2000; Rodriguez, Bollen, & Van de Sompel, 2006; Wilson, 2006; Case, 2007; Borgman, 2007; and Renear & Palmer, 2009).

Scientists, engineers, mathematicians, linguists, physicists, philosophers, psychologists, inventors, even some historians of science (like Derek de Sola Price, for example, one of the originators of what became known as bibliometrics and later scientometrics), and of course many librarians, were among those in this period striking out in new information systems directions.They worked in the organizations producing the great indexing and abstracting services mentioned above, in universities, in libraries, in government agencies, in corporations engaged in government-funded information research, and in information and research services in industry. Some also set up their own companies with which in the United States we associate such names as Saul Herner, Mortimer Taube, Calvin Moers, Joseph Becker, and Robert Hayes. The creation of these companies (many of them designed to market and implement the special indexing and retrieval systems their inventors had developed) was then a new phenomenon—excepting always Melvil Dewey's Library Bureau founded in the early 1880s (Weigand, 1996)—and remains little studied.

The individuals involved in all of these developments coalesced into scholarly and professional societies and associations that through their memberships, meetings, and publications laid claims to, and shaped, new domains of information research and development. In the United States, for example, in the early 1950s there was a "surge" of membership in the ADI originally founded in 1937 with a relatively limited remit. It became a general professional society and some thirty years later translated itself into the American Society for Information Science. But there were other important societies and organization that were carving out related areas of expertise and interest in the information domain such as, in the United States, the Association for Computing machinery (ACM) created in 1947, and the National Federation of Abstracting and Indexing Societies (NFAIS) created in 1958, as well as specialist sections that formed in the various library associations. In the UK, Jason Farradane, Brian Vickery, and others created the Institute for Information Science in 1958. Almost immediately after the war ended, FID and IFLA resumed their work.

The newly established UNESCO set up what became an active Department of Documentation, Libraries and Archives. Following a conference called in 1949 by UNESCO on abstracting services in science, the International Council of Scientific Unions (in association with UNESCO) established its Abstracting Board (ICSU-AB) as mentioned above. As time went by, all of these societies and associations—and there were others—helped to create the formal scholarly and professional environments needed to support the complex intellectual and professional allegiances of those interested in various aspects of information science and the system applications that were central to it.

New disciplinary influences

New players with a wide variety of disciplinary backgrounds entering the volatile domain of information systems and management during this period inevitably articulated new theoretical approaches to understanding the nature of information, information technology, and communication. Seminal works on operations research, cybernetics, information theory, and general systems theory appeared in the remarkably short period of 1948–1950.They could almost be said to have burst into the academic environment after the war, stimulating new specialties and offering challenging new perspectives on older ones. Their impact on what was becoming known as information science may be gauged by the fact that at a conference in the early 1960s on education for information science, it was suggested that the field might be approached from four different disciplinary points of view: systems theory, mathematics, behavioral sciences, and cybernetics (Swanson, 1964; Farkas-Conn, 1990, p. 199). Machlup and Mansfield observed that the twenty papers they had commissioned for their study of information identified an active concern for information in at least forty disciplines or subdisciplines. They concluded that in perhaps less than forty years, the disciplinary situation with respect to information had become so complex that to avoid confusion it was necessary to invoke the "power of the plural 's'." We should speak, that is to say, not of information science but of the information sciences (Machlup & Mansfield, 1983, pp. 13, 14, 19). Nevertheless, the intellectual ferment engendered by what might be described from their study as a babble of disciplinary tongues had the effect of stimulating creative discussion and experimentation. The multiplying, diversifying research and development projects that characterized this postwar, predigital information world might be usefully described using the terminological trajectory suggested by Hans Wellisch in 1972 as a movement from documentation, to information retrieval, to information storage and retrieval, to information science (Wellisch, 1972; see also Rayward, 1983).[4]

It is important, however, not to forget that during this whole period, the emphasis remained on finding solutions to problems posed by print-based information sources. It is this that allows me to distinguish this period from the postdigital period that followed. Infrastructures elaborated in the Gutenberg world remained fundamental. Book production continued to increase throughout the world (and though slowing is still increasing especially if digital books are counted with those that are issued in print formats). Scientific and scholarly societies, increasing in number along with various commercial publishers, were issuing more and more specialist journals, encyclopaedias, and handbooks. Libraries continued to attempt to channel this flood of print into their collections. The result was enormous backlogs and physical facilities that could no longer cope. The point can be dramatically made by anyone looking at the ever-growing numbers of the printed volumes of single titles such as *Chemical Abstracts* or the *Science Citation Index* that in this period were crowding ever longer stretches of shelving in library reference rooms.

The great national and research libraries were able to use developments in the technology of photolithographic offset printing to continue to print new editions of their card and slip catalogues. The publication of the British Museum's catalogue of printed books to 1955, for example, was completed in 1966 in 263 volumes using this method. The Library of Congress began to publish its catalogue of books represented by its printed card service from the service's beginning in 1901 up until July 31, 1942. This was issued in 167 volumes between 1942 and 1946 and was followed by a supplement for the next five-year period in 42 volumes that appeared between 1948 and1952. Perhaps the most spectacular and quickly outdated of these kinds of publication that harken back to the grandiose days of the late nineteenth century was the U.S. *National Union Catalogue, Pre-1956 Imprints.* This was completed in 1968 in 424 volumes. Even so, by 2005 over 25 percent of its content was not yet reflected in the holdings of the Ohio Center for College Libraries' (OCLC's) WorldCat (see below) (Beall & Kafadar, 2005). Microfilm technology also reached a kind of apogee of use in this period both for current searching in the literature but also, as a kind of extension of the work of the 1930s, for preservation filming and making available long runs of newspapers and scientific and other journals. Despite advances in digital scanning of microfilm, in many cases because of resource constraints these microfilm sets still remain the only form of access to the titles involved—and their difficulty of use and variable quality make them a scholar's bane.

Computers arrive

As the computer industry took hold in the early 1950s, it was clear that it held promise of solutions to some of the problems that were being produced by the rising quantities and complexity of documentary materials. The new technology made possible the automation of the operations that led to print publication. It also allowed the provision of enhanced services of various kinds (Selective Dissemination of Information [SDI], more complex search capabilities such as searching by chemical formula, and so on). The history of the information applications of computers is fundamental in this period. It is a story of complex and rapid developments that had their origins in the late nineteenth century in the invention by Hollerith of tabulating machines used at first for the compilation and analysis of census data. The use of these machines soon spread to information processing in commercial and industrial settings (Cortada, 1993, 1996). Otlet had at the time speculated about their potential for bibliographical purposes, but they began to make their way into and to initiate their work of transformation of Gutenburg's world only in the period immediately after World War II.

In the information environments I am discussing, the history of computer use segues through a number of stages involving specially configured machines often with the word "calculator" in their names (see, e.g., Segesta and Reid-Green's discussion of Harley Tillitt's use in the early 1950s of the IBM 701 Calculator [2002]) to general-purpose computers. There was an attempt as early as 1953, for example, to use the UNIVAC computer, the first commercial installation of which had occurred only in 1951, for information searching. In the early period of their history, their application was directed at the automation of various internal processing operations in general business and commercial organizations and in specifically "information" organizations such as indexing and abstracting services and libraries. They were used essentially to find more efficient and cost-effective ways of continuing to do or improve what was already being done. They were used, for example, to produce print-based services such as the *Citation Indexes* or *Chemical Abstracts*, or permuted single line (KWIC) book-like indexes, or catalogue cards for libraries, or even microfilm output catalogues (COM catalogues) the existence and horrors of which are now gratefully forgotten.

The MEDLARS system of the National Library of Medicine is a good example of an early computer application for information indexing and publication purposes. In 1964, as it was coming into service after several years of development, Frank Rogers described it in this way: "MEDLARS is a computerized information retrieval system with three major types of products: (1) one-shot demand searches on questions of great complexity, (2) recurring bibliographies in special fields of the medical sciences, and (3) composition of a comprehensive periodical index, the *Index Medicus*" (1964, p. 150). In effect it searched in batch mode machine-held files of bibliographic data to produce printed lists of various kinds. One of the major achievements of MEDLARS should not go unnoted. It was the development of the first fully functional, multifont, computer-based typesetting machine that was used for the production of *Index Medicus*. This was called Graphic Arts Composing Equipment (GRACE). The promise of the new computer technology for printing is reflected in the fact that GRACE had "the estimated typesetting power of fifty-five Linotype typesetting operators." Dee quotes an observation that appeared in the 1974 *Encyclopedia Britannica* not long after the system had been retired that "GRACE was as much a landmark in the history of phototypesetting as the Gutenberg Bible was in printing" (2007, pp. 418, 419).

But in the late 1950s and in the 1960s, current applications of what were still primitive computers did not last long because the technologies involved underwent extraordinarily rapid developments in capacity and versatility. Perhaps the next major information retrieval stage in their use was the emergence of database systems accessible through online search services, a form of networked connection that was entirely new and pioneered by MEDLARS when it transferred online in 1971 to become Medline. But even then, "the original system covered 239 journals, and the NLM boasted that it was 'capable of supporting up to 25 simultaneous users'"(Lindberg, 2000, p. 256). Nevertheless, it grew rapidly, and in the context of the technology of the time, its results could be interpreted less dismissively than perhaps Lindberg implies: "A year after MEDLINE began 150 institutions were connected to the system. Twenty-five libraries, on the average, were using it simultaneously, making 10,605 searches a month, or approximately 140,000 a year" (Miles, 1982, p. 385).

All of these new developments required the writing of complex programs and difficult negotiations within the relevant organizations, including international organizations, to create commonly accepted standards for file organization, for machine readable bibliographic description, and for data transmission across the new electronic networks. The new online services initially presented considerable difficulties of interrogation. Specially trained personnel skilled in query formulation were required; special command-driven terminals had to be developed. Bourne and Hahn give encyclopedic detail about the development in this period of online information services, especially what were to become the major commercial online bibliographic search services known as Dialog (produced by Lockhead), ORBIT (SDC), and others (2003).

An important development for libraries was the creation of MARC. "MARC is the acronym for MAchine-Readable Cataloging. It defines a data format that emerged from a Library of Congress-led initiative that began nearly forty years ago. It provides the mechanism by which computers exchange, use, and interpret bibliographic information, and its data elements make up the foundation of most library catalogues used today. MARC became USMARC in the 1980s and MARC 21 in the late 1990s."[5] MARC may be considered to have functioned as a "boundary object," to use the useful concept proposed by Susan Leigh Star and others. Created essentially for the pooling of bibliographic data and at first frequently used to produce catalogue cards, it has served as the basis for the negotiation of digital developments of various kinds across various communities (Star & Griesemer, 1989; Bowker, 1996; Star & Bowker, 1999)

Sally McCallum has described in some detail the development of the MARC format in the late 1960s. She mentions how quickly Fred Kilgour understood how it would facilitate the work of the Ohio Center for College Libraries (OCLC) that he was asked to organize in 1967. At first OCLC provided an online cataloguing service for its member libraries in Ohio using a specially modified Beehive terminal with a fixed line connection. But as the computer industry grew, so too did OCLC, which also developed an original research arm. It became national as the Online Computer Library Center. Today it is simply OCLC, Inc. (http://www.oclc.org/en-AU/worldcat//catalog.html) and manages an internationally developed cooperative database, WorldCat, that now comprises two billion bibliographic records[6] (OCLC, 2012; McCallum, 2002; Bourne & Hahn, 2003, pp. 344–348). With the advent in the early 1970s of regional "brokerage" centers, the bibliographic utilities that for a time were a major feature of the library and information landscape, the reach of OCLC was considerably extended beyond its origins in Ohio. Among the many cooperative networked-based functions these centers assumed for their members in the period under discussion were, for example, the training of searchers, the management of pooled subscriptions for and subscriber relationships with OCLC and other online services, the creation of local union catalogues, and the provision of consultancy services of various kinds. Several of the major cooperative networks such as WLN and RLIN were subsequently absorbed into OCLC. Others such as Illinet remain independent. Yet other once-active regional networks have only relatively recently merged into a super-bibliographic utitlity, Lyrasis, created in 2009 (http://www.lyrasis.org/About-Us.aspx)

Crisis

The new technologies and systems that multiplied and ramified into so many subject and user domains after the war seemed at first to promise simple relief from the increasing congestion, blockages, and delays of the established arrangements for information organization and dissemination. But following the early studies of Derek de Sola Price in 1961 and 1963 and others (see, e.g., Tague, Beheshti, & Rees-Potter, 1981; Renear & Palmer, 2009), the volume of available information was now understood to be growing exponentially. Its volume and complexity provoked a sense of looming crisis. The indexing and distribution mechanisms, the information structures and systems more generally that had been evolving for five hundred years to provide physical and intellectual access to publicly accessible recorded information and to official administrative records of various kinds proved inadequate to handle the increasingly heavy demands placed on them. "Work arounds" such as preprint exchanges of papers and reports, for example, or Garfield's *Current Contents* weekly service of the collected title pages of journals in various subjects emerged to try to overcome the increasing publication delays characterizing scientific communication. The creation of journals of "Letters" for the quick announcement of important observations provided an interesting echo of the Republic of Letters of the seventeenth and eighteenth centuries, but these journals were obviously limited in scope and were soon subject to the same pressures as their parent journals. For political, economic, disciplinary, and other reasons, governments, business, industry, and the various research communities, ever expanding and competitive, became evermore peremptory in their information requirements. Their alarm at what were perceived as growing information infrastructural inadequacies, especially in the public sphere, became evermore vociferous.

One form of government response was to commission the many studies and reports that were published in the period from the late 1950s through the 1980s. Harold Wooster, for example, has identified and annotated thirty such studies that were undertaken in the United States between 1958 and 1986 (1987). In the international arena, the situation was comprehensively assessed by three major international conferences. Following its 1946 Empire Scientific Conference, the Royal Society of London convened a Scientific Information Conference in 1948 that provides a kind of benchmark for analyzing subsequent developments in all aspects of the creation and management of scientific information systems and services (1948). This was followed ten years later in 1958 by the International Conference on Scientific Information in Washington. The conference was sponsored by the American Documentation Institute, the National Science Foundation, the National Academy of Science, and the National Research Council, and was based on a huge volume of preprint papers that were circulated as the basis for discussion at the conference. These papers in my view present the most detailed conspectus of an enquiry into developments in the field of information perhaps ever undertaken (International Conference, 1959). In 1971, UNESCO in association with the Council of Scientific Unions, responding to the sense that an international information crisis was impending, proposed that an international system should be developed to help in the worldwide coordination of the production and distribution of scientific and technical literature, UNISIST (which is a nonacronym).

Libraries, especially national and research libraries, had been evolving over the centuries of the Gutenberg era as a key component of public information infrastructures. Their principal aims had always been to record, collect, and make the products of the printing presses available both as soon as these products entered the market place but also and especially over time, for national and research libraries potentially forever. Working with IFLA, FID, and the International Council of Archives, in 1974 UNESCO developed the NATIS (National Information Systems) program to provide a kind of parallel to the UNSIST program for scientific information. By adopting this program, nations—it was hoped—would systematically establish national information policies and plans that could be integrated internationally. The greatest and most innovative libraries at this time had energetic and visionary leadership. They had developed comprehensive, sophisticated national and international cooperative systems of cataloguing, classification, and document sharing and delivery. They were early adopters of and subsequently continued to depend on the latest computer-based systems. Nevertheless, even they began to prove inadequate to deal with the escalating bibliographical problems that confronted them (Rayward, 2002).

It is perhaps simplistic but convenient to see a steady technological progression from punched card and microfilm-based systems of information storage and retrieval, through several generations of computer and networked systems, to the most recent developments arising from the advent of the Internet and the World Wide Web (Davis, 1937; Shaw, 1944; McCormick, 1963; Herner, 1984; Becker, 1984; Hirtle, 1989; C. Burke, 1992; Bowden, Hahn, & Williams, 1999; Griffiths & King, 2002; Rayward & Bowden, 2004; Williams, 2002a, 2002b; Renear & Palmer, 2009; Haig, 2011). Gutenberg's revolution still held sway if only feebly through the new information order of post–World War II up to the period of the late-1980s and even the beginnings of the 1990s. It was a world still to a large extent print based but struggling to adapt information and communications infrastructures for the effective management of increasing volumes of material appearing in new formats and based on new technologies. But with the widespread availability of the Internet in the 1980s and the advent of the World Wide Web in the early 1990s, we enter definitively the period of what I have called the third information revolution or information order.

The Third Information Revolution and the "Information Society"

Today's developments in digitization and globalization, one can argue, have led to such a radical overhaul and replacement of the previously established information infrastructures that I have been describing that they have created an information and communications revolution which seems to have no end in sight. This "revolution" has required the invention of a new nomenclatures—neologisms for new technologies, media and functions, a new kind of language that brings the revolutionary developments into the realm of the comprehensible and discussable. What is new must be named. But this language also sets these developments apart as something apparently without precedent. Take your pick: computers and the specialist terminologies associated with their operation, the Internet and the World Wide Web, the Semantic Web, Web 2.0, digitization, ubiquitous computing, ontologies, mark-up languages, E-preprint archives and institutional repositories, social networking, virtual reality, data curation, even telescience and telemedicine. Many traditional knowledge domains have their electronic dimension designated by an ever-present "E" for "electronic" (E-commerce, E-government, E-Science, E-learning) or are followed by "informatics" (social informatics, community informatics, biomedical informatics) to designate their basis in digital computing. Every one of the information services and projects that I have described above as emerging in the Gutenberg world of print, if it has continued, has been caught up in this new technological environment, from library catalogues to the Carte du Ciel, from collections of journals, books, manuscripts and archives to massive, continuously cumulating data collections: astrophysical, medical, genetic, chemical, economic, financial.

There is no doubt that modern society is being swept up into a high-tech telecommunications, networked, interactive environment of personal computing; digital radio, television and photography; and electronic mail. Small handheld devices to which almost anything digital can be downloaded or uploaded and shared, such as cell or mobile phones, and small portable devices such as tablet computers are increasingly ubiquitous, multifunctional, and becoming ever cheaper. Relationships between individuals and groups that in the past were defined, and perhaps constrained, by the limitations of the mails, the telephone, cumbersome document reproduction techniques—and even by the need for physical propinquity—have now been freed from these limitations by email, texting, teleconferencing, blogs, a plethora of online social networking sites, and new kinds of electronically-based communities and services that depend on communication that is instant, potentially simultaneous among many participants, and location free.

Renear and Palmer (2009) have suggested that a revolution in scientific communication was foreshadowed in the 1980s. It did not quite happen in the 1990s. But in their view, it is at last happening in the new millenium. Following this analysis, one might say that reality in a sense has caught up with rhetoric. Any discussion that involves references to revolutions implies dislocation and discontinuity. For some scholars, the transformative changes I have mentioned above herald the emergence of what is variously described as a postindustrial or post-Fordist or postmodern age, a network and surveillance society, a knowledge economy or digital capitalist economy that is radically different from what went before (the literature on these matters is vast but see, e.g., Webster, 2002; Kumar, 1995; European Commission, 1994).

Opposing voices stress the fact that, despite the undeniable magnitude and complexity of the changes that we are confronting, these changes are essentially new only in their velocity, convergence, and technological expression. From this point of view, all societies are fundamentally information societies, and what is continuous and evolutionary is as important as what seems to have been created by the upheavals of accelerating technological change (Robins & Webster, 1999; Rayward, 1996, 2008; Headrick, 2000; Black & Muddiman, 2007).

The future of information history

The problem is to understand what all of this means. How can what we are experiencing now offer us new perspectives on what has happened in the past? By studying the past, can we begin to formulate or at least clarify questions and issues that demand study now? The past is elusive and is reconstructed by historians, though upon evidence, variously and, while as a tribe they continue to exist, incessantly. The present is so chaotic and tumultuous that it too can only be caught and held momentarily by the conceptual and methodological approaches we impose upon it. It is in an instant also the past.

In writing the preceding pages, I have been drawing on a range of historical sources to make a point about the history of the ways in which over many centuries our Western societies have developed systems for the management of information and services that have been based on these systems. I have inevitably, idiosyncratically, created a long historical trajectory that to make comprehensible I have broken up into periods, a process that is always artificial and may appear inadequately justified. But these pages and this historical trajectory—and my own disciplinary and professional origins in librarianship, an occupation that has deepened and broadened in my lifetime as it has become essentially an aspect of what we now call information science—lead me to ask the question in the "blooming buzzing confusion" of the present: what is the future of the history of information science?

One approach to the future is to continue to do what we have been doing in the past, that is to take information issues, events, phenomena of any kind that are of interest and to trace their history as it has unfolded through time. This approach seeks to understand what became of them as the personal, social, technological, economic, and other circumstances in which they are embedded changed. It can lead us naturally to aspects of the modern period of the "digital revolution" and the "information society." It is an individualistic approach that can provide a historical framework, a historical perspective for what seems to be happening now. In my view this is how we conduct the history of information science at the moment. It is an approach that will continue and will continue to provide important insights.

Another approach is more purposive. It is to take what seems to be so distinctive about the present and ask: how and why did this come about? This may involve, say, a search for the roots of and the immediate precursor events to contemporary matters of interest such as information company takeovers, market movements, changing digital and other platforms, the latest information systems or media innovations. It might involve responses to current controversies and debates—privacy, copyright protection, opening up or restricting access to classified information, or even bullying and stalking on the social media that are both old and new kinds of information-mediated phenomena. An approach like this can be quite surprisingly rewarding. Peter Burke, for example, in the second volume of his *Social History of Knowledge* (2012), observes that his book has been motivated by the question "by what paths did we reach our present state of collective knowledge?" He sees his work as part of a growing body of studies on the history of knowledge that themselves have a not inconsiderable history. He plans a further book to be titled *From Gutenberg to Google* (Burke, 2012, pp. 1, 274–275), though he has already collaborated with Asa Briggs to produce *A Social History of the Media: From Gutenberg to the Internet*, now in its third edition (Briggs & Burke, 2010). In their turn, McNeeley and Wolverton (2008) have produced a volume that has a similar objective. *From Alexandria to the Internet* "is a history of the institutions of knowledge. It chronicles the six institutions that have dominated Western intellectual life since ancient times: the library, the monastery, the University, the Republic of Letters, the disciplines and the laboratory" (p. xvi). Hobart and Schiffman (2000) have created a similar perspective for the history of computing.

For other approaches one might take as examples Janet Abbate (1999) on the history of the Internet or Jospeh Reagle (2010) on Wikipedia, both serious and valuable studies of aspects of the emergence of our digital environment. Notably different kinds of study, methodologically and conceptually, are those associated with Susan Leigh Star and Geoffrey Bowker, who examine the complex, essentially unintuitive social and technological functions of information infrastructures (Star & Greisemer, 1989; Bowker, 1996; Bowker & Star, 1999). All of these approaches lead me to suggest that what we have been dealing with as the history of information science is an aspect of or stage in a much longer and more ramified history of information and communication infrastructures and the forces that created, sustained, and eventually changed them.

As we move into a world dominated by digital resources and new communications technologies, the world of print is no longer something we can take for granted. It has begun to take on a new historical salience, to raise new kinds of questions that need answering. Bonnie Mak's (2011) study of the history of the title page, a phenomenon that emerges in the medieval period of manuscript production and transitions through the

Gutenberg era of book production to the creation of Web-based homepages, has much to tell us about new approaches to information history that links the print and digital environments. In this context, David McKitterick offers an interesting rationale for his 2003 study, *Print Manuscript and the Search for Order, 1450–1830*:

> The flexibilities made possible by invention are not just the obvious ones distinctive to an individual medium: vellum or paper, pen, type or pixel. They also require an extension of thought, in that established practice must now operate in an environment larger both in its conception and in its organization. Conversely . . . new invention is inevitably judged and used according to familiar principles. Printing is a new way of writing. Computers offer new ways of publishing and sharing information resources. Even hypertext, for all its much vaunted possibilities, may be fundamentally defined as an extension of textual comparison of a kind familiar to scholarship since Politian . . . and others first worked to collate texts for the printing press in the late fifteenth century.

He goes on to observe that "the new drives out the old in more ways than just the technological. It also drives out former assumptions of reading and the old structures of thought." This provides him with the starting point for his new approach to the study of the relationship of manuscript and print (pp. 20–21).

In light of observations such as this, for me the question *What is the future history of information science?* needs to be broadened into something like *What is the future of the history of information or information infrastructures or the information society?* This in turn leads me to the observation that there are extensive but essentially discrete literatures that I have merely adverted to that bear on aspects of this broader question; on the history of the book, libraries and museums, computers, science and technology more generally and of course information systems and services. There is also a more general social and cultural historical literature, and a strong subset of this on the history of business and industrial organizations, that needs to be assimilated into how we might approach answers to the question.

It seems to me that the work of these variously denominated historians—of culture, society, business, books, libraries, museums, computing, information systems, and information science—have little overlap or interreference. All of the literatures I have mentioned represent a variety of historical approaches that have a potentially important bearing on the development of the kind of informatized world we live in today and the print-based world that lies behind it, but they do not cite each other. Their practitioners seem to live in separate worlds of enquiry. This leads me to suggest that the question *What is the future of the history of information science?* that I have broadened into the question *What is the future history of* *information, information infrastructures and the information society?* should be specified yet further into a question even more fundamental: *How are societies constituted, sustained, reproduced, and changed in part by information and the infrastructures that emerge to manage information access and use?* My sense is that we need to find a more inclusive and multidisciplinary approach to the history of information than has been possible so far, but the possibility of which is suggested by the studies that have been emerging in various disciplines in the last ten or fifteen years but, as it were, unbeknownst to each other! Could joint research projects be possibly undertaken involving subsets of historians of business and industry, technology, especially computing, social historians, historians of the book, and historians of information science, say? Are there different bodies of historical knowledge and research methodologies that might be usefully brought together in mutually conducted explorations of important information phenomena from Gutenberg to Google?

Notes

1. In a huge literature see, for example, the many-volume national histories of the book and treatises such as Johns (1998) and Eisenstein (1979).
2. I should acknowledge here that the idea of "Information Ages" has been used by several scholars, though in different contexts from my usage (e.g., Weinberger, 2008; Hobart & Schiffman, 2000).
3. Peiss describes her project in "Books on the Battleground," SAS Frontiers, University of Pennsylvania, retrieved October 5, 2013, from https://www.sas.upenn.edu/series/frontiers/books-on-battleground. See also Farkas-Conn (1990, Ch. 3).
4. For an extraordinarily detailed chronology of developments during this period (as of other periods), see Robert V. Williams's "Chronology of Information Science," the section for the 20th century and the subsections for the decades beginning 1950–54). Retrieved February 2, 2014, from http://faculty.libsci.sc.edu/bob/istchron/ISCNET/ISC20CEN.HTM
5. What is MARC 21? What does the acronym "MARC" mean? Retrieved October 5, 2013, from http://www.loc.gov/marc/faq.html#definition
6. "On May 4 [2013?], the University of Alberta Libraries created the 2,000,000,000th holding record in WorldCat, marking a major milestone for this unique library resource." Retrieved October 5, 2013, from http://www.oclc.org/worldcat.en.html

References

Abbate, J. (1999). *Inventing the internet.* Cambridge, MA: MIT Press.

Adkinson, B. W. (1978). *Two centuries of federal information.* Stoudsburg, PA: Dowden, Hutchinsom & Ross.

Alter, P. R. (1980). The Royal Society and the International Association of Academies 1897–1919. *Notes and Records of the Royal Society of London, 34*, 241–264.

Aubin, D. (2003). The fading star of the Paris Observatory in the nineteenth century: Astronomers' urban culture of circulation and observation. *Osiris, 18*(2nd series), 79–100.

Beall, J., & Kafadar, K. (2005). The proportion of NUC pre-56 titles represented in OCLC WorldCat. *College and Research Libraries, 66*(5), 431–435.

Becker, J. (1984). An information scientist's view on evolving information technology. *Journal of the American Society for Information Science, 35*, 164–169.

Binkley, R. C. (1936). *Manual on methods of reproducing research materials: A survey made for the Joint Committee on Materials for Research of the Social Sciences Research Council and the American Society of Learned Societies.* Ann Arbor, MI: Edwards Brothers.

Black, A., & Muddiman, D. (2007). The information society before the computer. In A. Black,

D. Muddiman, & H. Plant (Eds.), *The early information society: Information management in Britain before the computer* (pp. 3–52). Aldershot: Ashgate.

Borgman, C. (2007). *Scholarship in the digital age: Information, infrastructure, and the Internet.* Cambridge, MA: MIT Press.

Bourne, C. P., & Hahn, T. B. (2003). *History of online information services, 1963–1976.* Cambridge, MA: MIT Press.

Bowden, M. E., Hahn, T. B., & Williams, R. V. (Eds.) (1999). *History and heritage of science information systems: Proceeding of the 1998 conference.* Medford, NJ: Information Today, for the Chemical Heritage Foundation and the American Society for Information Science.

Bowker, G. C. (1996). The history of information infrastructures: The case of the International Classification of Diseases. *Information Processing and Management, 32*, 49–61.

Bowker, G. C., & Star, S. L. (1999). *Sorting things out: Classification and its consequences.* Cambridge, MA: MIT Press.

Briggs, A., & Burke, P. (2010). *A social history of the media: From Gutenberg to the Internet* (3rd ed.). Cambridge: Polity.

Buckland, M. K. (1992), Emanuel Goldberg, electronic document retrieval, and Vannevar Bush's Memex. *Journal of the American Society for Information Science, 43*, 284–294

Burke, C. (1992). The other Memex: The tangled career of Vannevar Bush's information machine, the Rapid Selector. *Journal of the American Society for Information Science, 43*(10), 648–657.

Burke, P. (2012). *A social history of knowledge II: From the Encyclopédie to Wikipedia.* Cambridge: Polity.

Bush, V. (1991 [1945]). As we may think. In J. M. Nyce & P. Kahn (Eds.), *From Memex to hypertext: Vannevar Bush and the mind's machine* (pp. 85–109). Boston: Academic Press.

Case, D. (2007). *Looking for information: A survey of research on information seeking, needs, and behavior* (2nd ed.). London: Academic Press.

Casey, R. S., & Perry, J. W. (Eds.). (1951). *Punched cards: Their applications to science and industry.* New York: Reinhold.

Chandler, A. (1977). *The visible hand: The managerial revolution in American business.* Cambridge, MA: Harvard University Press.

Chandler, A., & Cortada, J. W. (Eds.). (2000). *A nation transformed by information: How information has shaped the United States from colonial times to the present.* Oxford: Oxford University Press.

Cleverdon, C. W. (1960). ASLIB Cranfield research project on the comparative efficiency of indexing systems. *ASLIB Proceedings,12*, 421–431

Cleverdon, C. W., Mills, J., & Keen, E. M. (1966). *Factors determining the performance of indexing systems: Vol. 1: Design, Vol. 2: Results.* Cranfield, UK: Aslib Cranfield Research Project, Cranfield College of Aeronautics.

Cock, A. G. (1983). Chauvinism and internationalism in science: The International Research Council, 1919–1926. *Notes and Records of the Royal Society of London, 37,* 249–288.

Concilium Bibliographicum. (1910), Annual Report for 1910. *Annotationes Concilii Bibliographici. 6*(December), 23–31.

Cortada, J. W. (1993). *Before the computer: IBM, NCR, Burroughs, and Remington Rand and the industry they created, 1865–1956.* Princeton, NJ: Princeton University Press.

Cortada, J. W. (1996). *Information technology as business history: Issues in the history and management of computers.* Westport, CT: Greenwood Press.

Crestadoro, A. (1856). *The art of making catalogues of libraries: Or a method to obtain in a short time a most perfect, complete and satisfactory printed catalog of the British Museum Library.* London: Literary, Scientific & Artistic Reference Office.

Davis, W. (1937), How documentation promotes intellectual world progress. *The Science News-Letter, 32,* 229–231.

Dee, C. R. (2007). The development of the Medical Literature Analysis and Retrieval System (MEDLARS). *Journal of the Medical Library Association, 95*(4), 416–425.

Dewhirst, D. W. (1964). Introduction. In J. C. Houzeau & A. Lancaster (Eds.), *Bibliographie générale de l'astronomie jusqu'en 1880.* London: Holland Press.

Downs, R. B. (1949). Wartime co-operative acquisitions. *Library Quarterly, 19*, 157—165

Eisentstein, E. (1979). *The printing press as an agent of change: Communications and cultural transformations in early modern Europe* (Vols. 1–2). Cambridge: Cambridge University Press.

European Commission. (1994). *Europe and the global information society: Recommendations to the European Council.* Brussels: The Commission.

Farkas-Conn, I. (1990*). From documentation to information science: The beginnings and early development of the American Documentation Institute—American Society for information Science.* New York: Greenwood Press.
Gardey, D. (2008). *Ecrire, calculer, classer: Comment une révolution de papier a transformé les sociétiés contemporaines* (*1800–1940*). Paris: La Découverte.
Garfield, E. (1955), Citation Indexing for science: A new dimension in documentation through association of ideas. *Science*, *122*(3159), 108–11.
Garfield, E. (1977–1978). To remember Ralph Shaw. In *Essays of an Information Scientist* (Vol. 3, pp. 504–510). Philadelphia, PA: Institute for Scientific Information. Retrieved October 5, 2013, from http://www.garfield.library.upenn.edu/essays/v3p504y1977–78.pdf
Garfield, E. & Hayne, R. (1955). *Needed—A National Science Intelligence and Documentation Center.* Retrieved October 5, 2013 from http://www.garfield.library.upenn.edu/papers/natlsciinteldoccenter.html
Garvey, W., et al., (1972). Research studies in patterns of scientific communication I, II, and III. *Information storage and retrieval*, *8*, 111–122; 159–169; 207–221.
Garvey, W., & Griffith, B. (1964). The structure, objectives, and findings of a study of scientific information exchange in psychology. *American Documentation*, *15*, 258–267.
Geddes, P. (1915), *Cities in evolution: An introduction to the town planning movement and to the study of civics.* London: Williams, 1915.
George, L. A., & Blixrud, J. (2002). *Celebrating seventy years of the Association for Research Libraries, 1932—2002.* Washington, DC: Association for Research Libraries, 2002. Retrieved October 9, 2013, from http://www.arl.org/storage/documents/publications/celebrating-seventy-years-arl.pdf
Gill, D. (2008). [Entry in] *Complete dictionary of scientific biography* (vol. 5, pp. 403–406). Detroit: Charles Scribner's Sons.
Greenway, F. (1996). *Science International: A History of the International Council of Scientific Unions.* Cambridge: Cambridge University Press.
Griffiths, J.-M., & King, D. W. (2002). US information retrieval system evolution and development and evaluation (1945–1975). *IEEE Annals of the History of Computing*, *24*(3), 35–55.
Growoll, A. (1903). *Three centuries of English booktrade bibliography: An essay on the beginnings of booktrade bibliography since the introduction of printing and in England since 1595.* New York: Published for the Dibdin Club by M. L. Greenhalgh.
Haig, T. (2011). The history of information technology. *Annual Review of Information Science and Technology*, *45*, 431–487.
Headrick, D. R. (1981). *The tools of empire: Technology and European imperialism in the nineteenth century.* New York: Oxford University Press.
Headrick, D. R. (2000). *When information came of age: Technologies of knowledge in the age of reason and revolution, 1700–1850.* Oxford: Oxford University Press.
Henderson, M. (1999). Examples of early nonconventional technical information systems. In M. E. Bowden, T. B. Hahn, & R. V. Williams (Eds.), *History and heritage of science information systems: Proceedings of the 1998 conference* (pp. 169–176). Medford, NJ: Information Today.
Herner, S. (1984). Brief history of information science. *Journal of the American Society for Information Science*, *35*, 157–163.
Heuvel, C. van den, & Rayward, W. B. (2011). Mondothèque: A mulitmedia desk in a global Internet. In K. Börner & M. J. Stamper (Eds.) *Places and spaces: Mapping science.* Retrieved September 2, 2013, from http://scimaps.org/maps/map/mondoth%C3%A8que_multimed_123/
Hirtle, P. (1989). Historical note: Atherton Seidell and the photoduplication of library material. *Journal of the American Society for Information Science*, *40*(6), 424–431.
Hobart, M. E., & Schiffman, Z. S. (2000). *Information ages: Literacy, numeracy and the computer revolution.* Baltimore, MD: Johns Hopkins University Press.
Hurd, J. (2000). The transformation of scientific communication: A model for 2020. *Journal of the American Society for Information Science*, *51*(14), 1279–1283.
International Conference. (1959). *Proceedings of the International Conference on Scientific Information, November 16–21, 1958* (Vols. 1–2). Washington, DC: National Academies Press.
Johns, A. (1998). *The nature of the book: Print and knowledge in the making.* Chicago: University of Chicago Press.
Kumar, K. (1995). *From post-industrial to post-modern society: New theories of the contemporary world.* Cambridge, MA: Blackwell Publishers.

Lievrouw, L., & Carley, K. (1990). Changing patterns of communication among scientists in an era of "telescience." *Technology in Society, 12,* 457–477.

Lindberg, D. A. (2000). Internet access to the National Library of Medicine. *Effective Clinical Practice, 4,* 256–260.

Linder, L. H. (1959). *The rise of current complete national bibliography.* New York, Scarecrow Press.

Machlup, F., & Mansfield, U. (Eds.) (1983). *The study of information: Interdisciplinary messages.* New York: Wiley.

Mak, B. (2011). *How the page matters.* Toronto: University of Toronto Press.

Malclès, L.-N. (1989). *La bibliographie* (5th ed mise à jour par Andrée Lhéritier); Que Sais-je?; Paris: Presses Universitaires de France.

Manzer, B. M. (1977). *The abstract journal, 1790–1920: Origin, development, and diffusion.* Metuchen, NJ: Scarecrow Press.

Masure, L. (1913). Rapport sur la situation et les travaux pour l'année 1912. L'Institut International de Bibliographie Publication 123. Brussels: L'Institut.

McCallum, S. (2002). MARC: Keystone for library automation. *IEEE Annals of the History of Computing, 24*(2), 34–49.

McCormick, E. M. (1963). Bibliography on mechanized library processes: Appendix. In H. Goldhor (Ed.), *Proceedings of the Clinic on Library Applications of Data Processing* (pp. 157–171). Urbana, IL: Graduate School of Library Science, University of Illinois.

McCrimmon, B. (1981). *Power, politics, and print: The publication of the British Museum catalogue 1881–1900.* Hamden, CT: Linnet Books.

McKitterick, D. (2003). *Print, manuscript and the search for order, 1450–1830.* Cambridge: Cambridge University Press.

McNeeley, I. F., and Wolverton, L. (2008), *Reinventing knowledge: From Alexandria to the Internet.* New York: Norton.

Menzel, H. (1960). *Review of studies in the flow of information among scientists* (Vols. 1–2). New York: Bureau of Applied Social Research, Columbia University.

Miles, W. D. (1982). Evolution of computerized bibliographies. In *A history of the National Library of Medicine: The nation's treasury of medical knowedge* (chap. 20). Bethesda MD: National Library of Medicine.

Otlet, P. (1903). The science of bibliography and documentation. In W. B. Rayward (Ed. & Trans.), *International organisation and dissemination of knowledge: Selected essays of Paul Otlet* (pp. 71–86). Amsterdam: Elsevier.

Otlet, P. (1906). *Les aspects du livre: Conférence inaugurale de l'expostion du livre belge d'art et de littérature organisée à Ostende par le Musée du Livre, 14 juillet 1906. Publication VIII.* Brussels: Musée du Livre.

Otlet, P. (1907). La documentation. *Institut International de Bibliographie Bulletin, 12,* 3–11.

Otlet, P. (1934). *Traité de documentation: Le livre sur le livre: Théorie et pratique.* Brussels: Editiones Mundaneum, Palais Mondial. Retrieved September 1, 2013 from http://lib.ugent.be/fulltxt/handle/1854/5612/Traite_de_documentation_ocr.pdf

Otlet, P. & Goldschmidt, R. (1906). On a new form of the book: The microphotographic book [Sur une forme nouvelle du livre: Le livre microphotographique]. In W. B. Rayward (Ed. and Trans.), *International organisation and dissemination of knowledge. Selected Essays of Paul Otlet* (pp. 87–95). Amsterdam: Elsevier, 1990.

Peiss, K. (2007). Cultural policy in a time of war: The American response to endangered books in World War II. *Library Trends, 55*(3), 370–386.

Povey, M. (1998). *A history of the modern fact: Problems of knowledge in the sciences of wealth and society.* Chicago: University of Chicago Press.

President's Science Advisory Committee [the Weinberg Report] (1963). *Science, government, and information: The responsibilities of the technical community and the government in the transfer of information: A report of the President's Science Advisory Committee.* Washington, DC: The White House.

Price, D. J. de Sola (1961). Diseases of science. In *Science since Babylon* (rev. ed.). New Haven, CT: Yale University Press.

Price, D. J. de Sola (1963). *Little science, big science.* New York: Columbia University Press.

Rayward, W. B. (1975). The universe of information: The work of Paul Otlet for documentation and international organization (FID Publication 520). Moscow: Published for the International Federation for Documentation by All-Union Institute for Scientific and Technical Information (VINITI), USSR Academy of Sciences.

Rayward, W. B. (1983). Library and information sciences: Disciplinary differentiation, competition and convergence. In F. Machlup & U. Mansfield (Eds.), *The study of information: Interdisciplinary messages* (pp. 343–363). New York: Wiley.
Rayward, W. B. (1996). The history and historiography of information science: Some reflections. *Information Processing and Management, 32,* 3–17.
Rayward, W. B. (1997).The origins of information science and the work of the International Institute of Bibliography/International Federation for Documentation and Information (FID). *Journal of the American Society for Information Science 48*(4), 289–300.
Rayward, W. B. (2002). History of computer applications in libraries: Prolegomena. *IEEE Annals of the History of Computing, 24*(2), 4–15.
Rayward, W. B. (Ed.) (2008). European modernism and the information society: Introduction. In *European modernism and the information society* (pp. 1–26). Aldershot: Ashgate.
Rayward, W. B., & Bowden, M. E. (Eds.) (2004). *The history and heritage of scientific and technological information systems: Proceedings of the 2002 conference.* Medford NJ: Information Today, for the Chemical Heritage Foundation and American Society for Information Science and Technology.
Reagle, J. M. (2010). *Good faith collaboration: The culture of Wikipedia.* Cambridge MA: MIT Press.
Renear, A., & Palmer, C. (2009). Strategic reading, ontologies and the future of scientific publishing. *Science, 325*(5942), 828–832.
Renoliet, J.-J. (1999). *Unesco oubliée: La Société des Nations et la coopération intellectuelle (1919–1946).* Paris: Sorbonne.
Richards, P. S. (1994). Scientific information in wartime: The Allied–German rivalry, 1939–1945. Westport, CT: Greenwood Press.
Robins, K., & Webster, F. (1999). *Times of technoculture.* London: Routledge.
Rodriguez, M. A., Bollen, J., & Van de Sompel, H. (2006). The convergence of digital libraries and the peer-review process. *Journal of Information Science, 32*(2), 149–159.
Rogers, F. B. (1964). The development of MEDLARS. *Bulletin of the Medical Library Association. 52*(1), 150–151.
Royal Society (1948). *The Royal Society scientific information conference, 21 June–2 July 1948: Report and papers submitted.* London: The Society.
Schroeder-Gudehus, B. (1973). Challenge to transnational loyalties: International scientific organizations after the First World War. *Science Studies, 3,* 93–118.
Scott, E. W. (1953). New patterns in scientific research and publication. *American Documentation, 4,* 90–95.
Segesta, J., & Reid-Green, K. (2002). Harley Tillitt and computerized library searching. *IEEE Annals of the History of Computing, 24*(3), 23–34.
Shaw, R. (1944). Should scientists use microfilm? *The Library Quarterly, 14*(3), 229–233.
Standage, T. (1998). *The Victorian internet: The remarkable story of the telegraph and the nineteenth century's online pioneers.* New York: Walker and Co.
Star, S. L., & Bowker, G. (1999*). Sorting things out: Classification and its consequences.* Cambridge MA: MIT Press.
Star, S. L. & Griesemer, J. (1989). Institutional ecology, "translations" and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–1939. *Social Studies of Science, 19*(3), 387–420.
Swanson, D. (Ed.) (1964). *The intellectual foundations of library education: The twenty-ninth conference of the Graduate Library School, July 6–8, 1964.* Chicago: University of Chicago Press.
Tague, J., Beheshti, J., & Rees-Potter, L. (1981). The law of exponential growth: Evidence, implications and forecasts. *Library Trends, 30*(1), 125–150.
Tate, V. D. (1950). Introducing American Documentation. *American Documentation, 1,* 3 –7
U.S. Office of Scientific and Technical Information. (2000). *History of the vision.* Reports prepared for Workshop on a Future Information Infrastructure for the Physical Sciences, Washington, DC, May 30–31, 2000. Retrieved February 24, 2014, from http://www.osti.gov/home/sites/www.osti.gov.home/files/imported/physicalsciences/wkshprpt.pdf
Vaden, W. M. (1992). *The Oak Ridge Technical Information Center: A trailblazer in federal documentation.* Oak Ridge, TN: US Department of Energy Office of Scientific and Technical Information.
Varlejs, J. (2004). The technical report system and its impact on post-World War II information

systems. In W. B. Rayward & M. E. Bowden (Eds.), *The history and heritage of scientific and technical information systems* (pp. 89–99). Medford, NJ: Information Today.
Ward, H. B. (1921). Herbert Haviland Field. *Science* (New Series) *54*, 424–428.
Webster, F. (2002). *Theories of the information society* (2nd ed.). London: Routledge.
Weigand, W. (1996). *Irrepressible reformer: A biography of Melvil Dewey*. Chicago: American Library Association.
Weinberger, D. (2008). *Everything is miscellaneous: The power of the new digital disorder*. New York: Holt.
Wellisch, H. (1972). From information science to informatics: A terminological investigation. *Journal of Librarianship, 4*(1), 157–187.
Wells, H. G. (1918). *In the fourth year: Anticipations of a world peace*. New York: Macmillan.
Williams, E. (1953). *Farmington Plan Handbook*. Bloomington, IN: Association of Research Libraries.
Williams, R. V. (2002a). *Chronology of information science and technology*. Retrieved February 24, 2014, from http://faculty.libsci.sc.edu/bob/istchron/ISCNET/ISCHRON.HTM
Williams, R. V. (2002b).The use of punched cards in US libraries and documentation centers, 1936–1965. *IEEE Annals of the History of Computing, 24*(2), 16–33.
Wilson, T. D. (2006). On user studies and information needs: 60 years of the best in information research. *Journal of Documentation, 62*, 658–670.
Woolston, J. E. (2004). Intergovernmental cooperation for mission-oriented information syststms: A memoir. In W. B. Rayward & M. E. Bowden (Eds.), *The history and heritage of scientific and technical information systems* (pp. 373–390). Medford, NJ: Information Today.
Wooster, H. (1987). Historical note: Shining palaces, shifting sands: National information systems. *Journal of the American Society for Information Science, 38*(5), 321–335
Wouters, P. (1999). *The citation culture*. Unpublished doctoral dissertation, Universiteit van Amsterdam.
Yancey, R. (2005). *Fifty years of citation indexing and analysis*. Retrieved September 4, 2013 from http://thomsonreuters.com/products_services/science/free/essays/50_years_citation_indexing/
Ziman, J. (1969). Information, communication, knowledge. *Nature, 224*, 318–324.

W. Boyd Rayward is emeritus professor in the Graduate School of Library and Information Science of the University of Illinois and in the School of Information Systems, Technology and Management of the University of New South Wales. He was educated in Australia and the United States. His PhD is from the University of Chicago. He has held professorial and decanal positions in the University of Chicago and the University of New South Wales. In 2000 he was made the 25th Honorary Member of the Australian Library and Information Association. He is the recipient of the 2004 American Society for Information Science and Technology Research Award. His recent research has involved studies of Paul Otlet's ideas as they relate to the Internet, the World Wide Web, and the beginnings of modern information science, a number of utopian schemes of knowledge organization including H. G. Wells's idea of a world brain, and, from an historical point of view, the implications of digitization and networking for libraries and museums. Among his publications are *The Universe of Information: The Work of Paul Otlet for Documentation and International Organization,* 1975, translated into Russian and Spanish; *International Organisation and Dissemination of Knowledge. Selected Essays of Paul Otlet,* 1990; *European Modernism and the Information Society,* 2008; chapters in *Paul Otlet* (*1868–1944*) *Fondateur du Mundaneum: Architect du savoir, Artisan de paix*, 2008; *Mundaneum: Archives of Knowledge*, 1910. His *Mondothèque: A Mulitmedia Desk in a Global Internet* (with Charles van den Heuvel) was issued on the Web in 2011 in the series "Places and Spaces: Mapping Science." His edited book, *Information Beyond Borders: International Intellectual and Cultural Exchange in the Belle Epoque,* was published in April 2014 by Ashgate.