Scholarly Information Practices in the Online Environment

Themes from the Literature and Implications for Library Service Development

Carole L. Palmer
Lauren C. Teffeau
Carrie M. Pirmann

Graduate School of Library & Information Science (GSLIS)
Center for Informatics Research in Science & Scholarship (CIRSS)
University of Illinois at Urbana-Champaign

A publication of OCLC Research

Scholarly Information Practices in the Online Environment: Themes from the Literature and Implications for Library Service Development
Carole L. Palmer, Lauren C. Teffeau and Carrie M. Pirmann for OCLC Research

January 2009

OCLC Research
Dublin, Ohio 43017 USA
www.oclc.org

ISBN: 1-55653-408-6 (978-1-55653-408-9)
OCLC (WorldCat): 298733494

Please direct correspondence to:
Constance Malpas
Program Officer
constance_malpas@oclc.org

Suggested citation:
Palmer, Carole L., Lauren C. Teffeau and Carrie M. Pirmann. 2009. Scholarly Information Practices in the Online Environment: Themes from the Literature and Implications for Library Service Development. Report commissioned by OCLC Research. Published online at:
www.oclc.org/programs/publications/reports/2009-02.pdf

Contents

Tables

Figures

Introduction

Research libraries exist to support scholarly work. In recent years, the literature on scholarly practices and information use has been growing, and research libraries should be prospering from this increased base of knowledge. Unfortunately, the profession has no effective means for systematically monitoring or synthesizing the published results. This review begins to address the problem by reporting on the state of knowledge on scholarly information behavior, focusing on the information activities involved in the research process and how they differ among disciplines. It provides an empirical basis for identifying promising directions and setting priorities for development of digital information services to support and advance scholarship.

Preparing this report required the project team to make decisions about what publications to cover, what results to extract, and how to integrate and present the many valuable but often incongruous findings on scholarly information behavior. Across studies there is considerable variation in how the object of study is defined and in how data is collected and analyzed. The variety of approaches is a natural outcome of the increase in number and sophistication of studies in recent decades and the complexity of the processes under investigation. The challenges of designing and conducting a solid study of scholarly information behavior are many, but they are rarely apparent when reading the published reports.

Scholars and scientists carry out layers of physical and intellectual activity through a complicated mix of mundane and seemingly idiosyncratic tasks that result in a range of immediate and long-term outcomes. It is difficult to collect data that captures these socio-cognitive processes, and interpreting that data in ways that advance our understanding is even more challenging. The value and uses of information—individual items or entire genres—can change over time, at a micro level as scholars gather, evaluate, analyze, assimilate and write, and at a more macro level as their ideas evolve, projects move forward and careers unfold. In our studies of scholarly information work, we have seen how a highly influential text can move a scholar into a new research project but then become overshadowed in the course of inquiry, with no trace left in the final, tangible scholarly product. On the other hand, we have also seen how scholars will reference materials from a diverse range of subject areas that reaches far beyond what they can readily recall as part of their information repertoire. These twists, turns, perceptions and practices are part of the intricate constellation of information activities that generate new scholarship and that we strive to document and understand through empirical studies of scholarly information behavior. The term “information behavior” has become the field’s preferred term for studies of information needs and uses, but here, and in previous related papers, we use the terms “information practices” and “information work”

since they we believe they are a better representation of the social aspects of scholarly activities and the purposeful, workaday nature of how scholars spend their time.

Scope of the literature

The literature on scholarly information behavior dates back at least to the reports from the 1948 Royal Society Scientific Information Conference and the 1952 Chicago School symposium on specialized information (Egan, 1954). Since that time, there has been a steadily increasing stream of research that has moved beyond the sciences to address the range of disciplines. By the 1980s, user studies research had taken hold as a significant subfield in LIS, and much of the research on scholarly groups produced over the decades is still highly relevant. For example, in the early digital era, RLG released a series of studies that provided a broad examination of information needs across the humanities, social sciences and sciences. The three reports covered a total of 20 disciplines, profiling the nature of information, its uses and sources in each field (Gould, 1988; Gould & Handler, 1989; Gould & Pearce, 1991). Around the same time, a book-length study of the work processes of art historians was published by the J. Paul Getty Trust and the Institute for Research in Information and Scholarship at Brown University (Bakewell, Beeman, & Reese, 1988). These two contrasting approaches stand as exemplars of the broad and deep analyses needed to understand how to develop effective information resources and tools for scholars.

The results from these and other earlier works still hold implications for contemporary research libraries. In addition to supplying benchmarks from the past for assessing consistency and change over time, they contain important insights on information work before it was influenced by current technologies. Some information practices have not been altered in any fundamental way in the digital environment, but many may be enhanced or advanced with new information resources and tools. For example, the table below presents a distillation of results from the RLG reports on the types of information sources found to be of importance across the various disciplines studied. What has changed in the digital environment is not the value of these kinds of sources but rather how they are searched, accessed and used in the scholarly process. Therefore, while recent literature is emphasized in the review, selected earlier studies have been consulted dating back to 1962.

Table 1: Source materials by discipline reported in RLG reports

Discipline	Information Sources											
	Journals	Mono-graphs	Conference proceedings	Data sets/ collections	Audio-visual materials	Archival materials	Preprints/ working papers	Disser-tations	Government documents	Technical reports	Patent literature	Other Sources Noted
Sciences (Gould & Pearce, 1991)												
Astronomy	✓		✓	✓	✓	✓	✓			✓		star charts; photographic plates; satellite imagery
Biology	✓		✓	✓	✓						✓	museum collections
Chemistry	✓	✓	✓							✓	✓	handbooks; physical and chemical properties databases
Computer Science	✓		✓				✓			✓		
Engineering	✓	✓	✓	✓						✓	✓	standards literature
Geosciences	✓	✓	✓	✓	✓	✓	✓	✓	✓			maps; field guides
Math	✓	✓	✓				✓					translations
Physics	✓	✓	✓	✓			✓			✓		handbooks; letters journals
Social Sciences (Gould & Handler, 1989)												
Anthropology	✓	✓	✓	✓	✓		✓		✓			museum collections; field notes; foreign language texts; grant information
Economics	✓			✓			✓		✓			international literature and data; disaggregated data
Political Science	✓		✓	✓			✓		✓			newspapers; policy papers; foreign government documents
Psychology	✓	✓	✓	✓				✓		✓		grant information
Sociology	✓	✓	✓	✓					✓			
Humanities (Gould, 1988)												
Art History	✓	✓	✓		✓	✓		✓				museum/exhibition catalogs; artist books; trade catalogs
Classical Studies	✓				✓	✓						papyri; inscriptions; iconography
History	✓	✓		✓	✓	✓		✓	✓			newspapers; popular culture materials; oral history archives; presidential libraries
Linguistics	✓	✓			✓		✓	✓				grammars; field notes
Literature	✓	✓			✓	✓						foreign language texts
Music	✓	✓			✓	✓						musical scores; opera libretti
Philosophy	✓	✓	✓			✓						
Religion	✓	✓				✓		✓				

As suggested above, it is complicated to integrate or make close comparisons among different kinds of studies. Quantitative and qualitative approaches make distinct contributions and together provide complimentary perspectives and results. For example, ethnographic data provide richer and more nuanced analyses of research as it happens, while quantitative surveys produce more general results on patterns and trends in information behavior. In recent years, qualitative studies have become more common and are therefore strongly represented in this review. Coverage of bibliometric studies is limited, since they tend to tell us more about the structure and flow of information than the actual work practices of scholars. Across studies the groups of scholars and scientists studied have been scoped in different ways, ranging from very broad classes (e.g., science, humanities) to more narrowly defined disciplines (e.g., Jewish studies, literary criticism, genomics), and mixed groups of interdisciplinary scholars working in many different research areas. Since it was not possible to align and integrate results by the population studied, our approach was to bring together findings on scholarly information activities, associating studies of similar domains and providing loose comparisons where possible.

Most of the literature covered is from journal publications in library and information science (LIS), and a number of important books and professional reports have also been included. Selected items from cognate fields in the social sciences and other information science domains, such as computer supported cooperative work (CSCW), are also discussed. Other research areas such as human-computer interaction and internet studies have not been included, partly due to space constraints but also because their application to information services is often less direct. Because of our focus on disciplinary practices, we have not included research from LIS or cognate areas that examines information behavior primarily from the perspective of the individual. Many such studies have been important in demonstrating how local context influences information behavior, although the definition of context has been debated and inconsistently applied (Courtright, 2007; Talja, Keso, & Pietilainen, 1999). Our focus in gathering literature for review was on more socio-cultural approaches that interpret information behavior as practiced within a discipline or field of study. As suggested by Hjørland and Albrechtsen (1995), since domain based studies of information seeking and use aim to represent consensus among communities of scholars, they are potentially more explanatory than those that analyze the behavior of discrete individuals.

Analytical framework

To synthesize the large and diverse body of literature on disciplinary information practices, we have concentrated on relating results on specific information activities provided by each study. We began by drawing from our previous review of scholarship and disciplinary practices (Palmer & Cragin, 2008), incorporating additional library oriented literature and covering a fuller range of information activities involved in the process of research. Adapting Unsworth's (2000) concept of "scholarly primitives," we derived a framework of scholarly information activities and primitives to guide

discussion and to serve as points for comparison across domains. Our aim has been to advance understanding of the information work of scholarly communities, not the behaviors of individual researchers. Scholarship is a dynamic enterprise, however, and scholarly communities can be defined in many ways.

Many studies are designed to investigate standard academic structures and disciplinary categories. However, we know from our previous work on interdisciplinary research processes that it can be counterproductive to assume that formal academic departments are true representations of scholarly affinities (Palmer 1996, 1999a, 2001a, 2005; Palmer & Neumann, 2002). Scholars regularly cross disciplinary boundaries in their information work, and recent studies have verified the importance and prominence of interdisciplinarity at research universities (e.g., University of Minnesota Libraries, 2006). Under these conditions, studies of scholarly groups need to take into account of the "trading zones" that emerge as researchers exchange their expertise and products to solve research problems (Galison, 1996).

The base of literature reviewed may not adequately reflect the dynamics of how researchers interact with information and people across fields and specialties, but our activity based framework is useful for foregrounding information work processes rather than a priori assumptions about disciplinary structures that may be built into the design of individual studies. At the same time, in gathering and discussing the research related to each activity, disciplinary distinctions across studies can easily be discerned. In addition, the review incorporates the growing body of work on information practices of interdisciplinary scholars and cross-disciplinary collaborations. As a whole, the activity centric narrative offers a landscape view of the many interdependent information processes involved in scholarly work.

Scholarly information activities and primitives

As discussed by Unsworth (2000), *scholarly primitives* are basic functions common to scholarly activity across disciplines. He clarified the concept with a list of primitives—discovering, annotating, comparing, referring, sampling, illustrating and representing—and provided further explanation with examples from humanities computing projects. Our concept of *scholarly information activities* is related but emphasizes the explicit role of information in the conduct of research and production of scholarship (Palmer & Cragin, 2008). The notion of the primitive is distinct in that it is meant to refer to activities that are common across disciplines, at least within the humanities where the concept was originally developed and applied, and the examples provided by Unsworth suggest that the activities are relatively discrete in nature. In our application, we refine the concept further by emphasizing a sense of the primitive as something at the base or beginning of a larger process. For example, in our framework, searching for information is interpreted as a scholarly information

activity, while the more granular activities of chaining and browsing that contribute to the larger search and discovery process are considered primitives.

What qualifies strictly as an information activity or a constituent primitive stands as a basic information science research question in need of further empirical investigation. For example, the University of Minnesota Libraries (2006) took a different approach in their project to develop a framework for assessing support for scholarship on their campus. They identified four general primitives—discover, gather, create and share—that "described the range of activities undertaken by scholars throughout the research process" (p. 38). Thus, while firm criteria for determining primitives have yet to be developed, the concept has proven intuitive and valuable in both the digital humanities and in LIS. For our purposes, the distinction between more general information activities and associated primitives has been helpful for structuring the array of findings on scholarly information work that currently exist in the literature. Both activities and primitives, we believe, tend to be common across disciplines and integral to how scholars create new works. Additionally, they can happen at any stage of research, within data collection, analysis, and dissemination processes, or during the more formative stages of a research project.

Our activity centric approach is reminiscent of some existing models of information seeking and use in LIS. One of the most well-known, developed by Ellis and colleagues, identified six common processes—starting, chaining, browsing, differentiating, monitoring and extracting—based on qualitative, comparative analysis of information seeking in the social sciences, physical sciences, and literature (Ellis 1989, 1993; Ellis, Cox, & Hall, 1993). Competing process models exist (e.g., Foster, 2004; Kuhlthau, 1991), and revisions have been proposed based on new research. In particular, Meho and Tibbo (2003) suggested adding a number of activities to the Ellis model, such as accessing, networking, and verifying, drawing on data from e-mail interviews with social scientists working in the research area of stateless nations. In a multi-method qualitative study, Palmer and Neumann (2002) showed that for interdisciplinary humanities scholars such a model should include the exploring and translating activities involved in working with information and colleagues in outside domains. As the case of Ellis's model demonstrates, our understanding of the information activities that make up scholarly work, and how they map to scholarly communities, remains questionable and incomplete.

The sections that follow present the literature on scholarly information work framed around five core scholarly activities: searching, collecting, reading, writing and collaborating, with two or more primitives distinguished for each activity. Four cross-cutting primitives that are associated with more than one activity are also covered and serve as an important indicator of how the processes involved in the conduct of research and scholarship overlap and interact. Additionally, in the electronic environment "the flow of seeking, using, and creating information is becoming seamless" and new tools and resources are altering how scholars interact with information (Borgman, 2000). The activity/primitive framework allows us to see the components of this increasingly fluid set of

processes and how they may vary in application by researchers working in different fields. This report does not offer a comprehensive account of all possible activities and primitives involved in scholarly information work. The scheme, outlined below, was derived from the literature and enumerates those with a base of findings from multiple empirical studies across disciplines.

Table 2: The five core scholarly activities and their primitives

1. Searching
    - 1.1 Direct searching
    - 1.2 Chaining
    - 1.3 Browsing
    - 1.4 Probing
    - 1.5 Accessing
2. Collecting
    - 2.1 Gathering
    - 2.2 Organizing
3. Reading
    - 3.1 Scanning
    - 3.2 Assessing
    - 3.3 Rereading
4. Writing
    - 4.1 Assembling
    - 4.2 Co-authoring
    - 4.3 Disseminating
5. Collaborating
    - 5.1 Coordinating
    - 5.2 Networking
    - 5.3 Consulting
6. Cross-cutting Primitives
    - 6.1 Monitoring
    - 6.2 Notetaking
    - 6.3 Translating
    - 6.4 Data Practices

Searching

Searching involves deciding where and how to look for information. It may be performed with a single query and may result in the retrieval of one bibliographic record or one fact, but more often it is a complex and iterative process. It is a particularly important aspect of the “starting” or “opening”

stages of research identified in process models of information seeking (e.g., Ellis 1993; Ellis et al., 1993; Foster, 2004; Meho & Tibbo, 2003). The searching activity in itself may open in a number of ways—with references to a current article or book, advice from a colleague, or keywords aimed at finding specifics or for exploring a new area. The primitives associated with the searching activity—direct searching, chaining, browsing, probing, and accessing—are distinctions that apply in both the analog and digital information environment.

Recent studies have tended to investigate searching on the Web, and searching for information online is clearly a widespread practice across fields, but the actual impact of the shift to digital search systems remains difficult to assess in any comprehensive way. One recent campus-wide survey reported that researchers in science and medicine almost exclusively preferred to search using electronic resources (Hemminger, Lu, Vaughan, & Adams, 2007). Approximately half of the interdisciplinary scientists surveyed in another study reported that their searching habits were markedly different from five years earlier due to the availability of digital resources (Murphy, 2003). As would be expected, studies of scholars have consistently found high use of search engines, especially Google, which allow concurrent search across a wide and diverse array of sources. A recent study examined decades of citations and the impact of online availability, showing that patterns have shifted as print browsing has become eclipsed by online searching. It cautions that scholars appear to be avoiding older, but relevant, literature and to be focusing only on previously cited sources, resulting in the use of a narrower, more homogenized range of literature (Evans, 2008).

Direct searching

Direct searching occurs when a scholar has a well-defined goal. For example, they may be looking for information on a particular chemical compound or trying to find a particular journal article. In most cases, direct searching is conducted with familiar keywords, names or other known terms in databases, online catalogs, search engines and online journals (Foster, 2004). Keyword searching predominates in digital resources, as seen in a survey of users of a Finnish national digital resource that showed a high level of keyword searches in both journal databases (63%) and reference databases (53%) (Vakkari & Talja, 2006). Keywords have been found to be important to historians for locating items known to be in an archive (Duff & Johnson, 2002) and for humanities scholars who frequently search for names, places, titles of works, and other proper nouns associated with familiar materials (Bates, 1994; Bates, 1996a; Bates, 1996b; Bates, Wilde, & Siegfried, 1995; Siegfried, Bates, & Wilde, 1993; Wiberley, 2003). In the humanities, keywords that represent discipline-specific terms and other indicators of domain knowledge have also been shown to be important in formulating effective search strategies (Buchanan, Cunningham, Blandford, Rimmer, & Warwick, 2005).

Over the course of a research project, scholars use direct searching to confirm their ideas and verify facts. This kind of confirmation searching is used by humanities scholars to solidify their ideas and assist in recall of previous work done in a particular area. Studies of scientists, however, have shown that their direct searching tends to be aimed at specific questions or a problem at hand when conducting an experiment or writing up results (Palmer, 2005), or for checking the accuracy of information in hand (Ellis, 1993). Searching to check for accuracy of quotes and references has been observed in the searching practices of interdisciplinary scholars (Foster, 2004; Meho & Tibbo, 2003), and for women's studies scholars, identifying gaps in the literature was found to be particularly important at the end of a project (Westbrook, 2003). More uniquely, since interdisciplinary researchers often identify information that is "intellectually distant or from unknown sources," another layer of confirmation searching may be required "to interpret, verify and anchor the new material" (Palmer, 2005, p. 1144).

In the online environment, searchers tend to work more quickly and less deeply. A search pattern documented in one study of neuroscientists using PubMed is typical. Searchers faced with large retrieval sets only selected items from the first few pages of results, although some did export result sets into bibliographic software for further review at a later time. Few searchers changed their queries or used the advanced search modes to get better results (Vibert, Rouet, Ros, Ramond, & Deshoullieres, 2007). It is common knowledge that search queries that contain imprecise terminology may result in very large retrieval sets, and misspellings may result in no results at all, yet many databases and online catalogs do not offer users suggestions for improving a query. Humanities scholars have noted their continued appreciation of library card catalogs for being more forgiving of minor terminology issues (Brockman, Neumann, Palmer, & Tidline, 2001). Search system recommendations, based on an evaluation of the University of California's library services, have included incorporation of multi-lingual spell-checking, increased sensitivity to obscure scholarly terms, and presentation of options for alternative and related terms and topics. Provision of search expansions into other catalogs, like WorldCat, Amazon and other search engines, was also suggested, as well as access to librarian assistance via chat or e-mail reference (Bibliographic Services Task Force, 2005).

Chaining

Scholars depend on bibliographic references found in scholarly books, journal papers and Web sites to identify items to consult or read. This practice of backward chaining, or footnote chasing, has been confirmed as a distinct and prominent searching technique used across scholarly groups, ranging from humanities graduate students to Jewish studies scholars, and from sociologists and computer scientists to researchers in economics and engineering (Barrett, 2005; Bronstein, 2007; Buchanan et al., 2005; Covi, 1999; Ileperuma, 2002; Vakkari & Talja, 2006; Westbrook, 2003). By following references, scholars are able to trace previous relevant publications. Forward chaining, or

citation searching, is the correlate practice for finding subsequent relevant publications. Bibliographic connections of this kind have been used for centuries to identify relationships among texts, but with networked information technologies, this kind of linking has exploded as scholars more readily chain through digital content (Bates, 2002).

For humanities scholars, chaining provides an important path to secondary materials via books, articles and reviews (Bates, 1994; Bates, 1996a; Bates, 1996b; Bates, Wilde, & Siegfried, 1995; Siegfried, Bates, & Wilde, 1993). But, other kinds of value are inherent in the practice of "mining" the expert bibliographies complied by others. Chaining works to build an understanding of the landscape of a field, shortens research time on a project, and helps in identifying the most important works on a topic (Brockman et al., 2001). One study found that the "seed documents" used for chaining by humanities scholars were particularly valuable for identifying sources not listed in standard indexes (Green, 2000). Among scientists, chaining has been shown as a key strategy for identifying older information for use in both teaching and research (C. M. Brown, 1999).

The notion of chaining can be extended to include sources discovered through personal contacts, where the "link" takes the form of a suggestion from a colleague or collaborator (Meho & Tibbo, 2003). Evidence of this type of interpersonal chaining is found in studies across disciplines, and it is also discussed below as a kind of "consulting," a primitive associated with collaborating activities. Women's studies scholars, library and information scientists, graduate students in the humanities, sociologists, interdisciplinary scholars and astronomers have all been shown to rely on their colleagues for recommending relevant materials (Barrett, 2005; Covi, 1999; Spanner, 2001; Tenopir, King, Boyce, Grayson, & Paulson, 2005; Westbrook, 2003; Zhang, 2001). A recent study reported that "using colleagues as information sources for journals was more typical in humanities than in other fields," even though the act of chaining in general was a significantly more important approach in economics and engineering compared to humanities and medicine (Vakkari & Talja, 2006). Computer scientists have been relying on e-mail discussion lists to solicit references for some time (Covi, 1999). The practice may be more irregular with interdisciplinary scientists, but it can produce very high quality information. One study documented a case where a scholar sent a "cold contact" e-mail to a high-profile expert in an outside field and received a lengthy and highly valuable bibliography in response (Palmer, 2005).

Chaining on the Web has been referred to as "quasi-footnote chasing," since it usually combines linking among various kinds of digital content with search engine queries (Brockman et al., 2001). Studies have shown how geographers move between digital and print resources while chaining, performing iterative cycles of searching and working by following links in Web sites and online journal articles, tracking citations in book reviews and in print publications, and searching library catalogs (Borgman et al., 2005). A study of how scholars use e-texts suggested that the difference between traditional chaining and browsing disappears in the online environment and is replaced

with the practice of "netchaining," which establishes and shapes "online information chains that link sources and people" (Sukovic, 2008, p. 274-275).

Browsing

Browsing has long been recognized as an important and widely practiced information behavior (Bates, 2007; Chang & Rice, 1993; O'Connor, 1993). Unlike directed searching and chaining, browsing tends to be open ended with the searcher looking through a body of assembled or accessible information. As with other types of searching, the Web has had a tremendous impact on what and how scholars browse, and on the rate at which they can move through digital material from a diverse array of sources. For example, a study combining deep log analysis and surveys of Web usage found that users often engage in "bouncing" or "flicking," moving rapidly from site to site and only occasionally returning to explore material in more depth (Nicholas, Huntington, Williams, & Dobrowolski, 2004). Other studies confirm that print browsing continues to be of value to scholars. One large survey of scholars in the humanities and social sciences reported that approximately 80% considered browsing the library shelves to be an important, although infrequent, activity (University of Minnesota, 2006). Among studies of scholarly information use more generally, browsing has been strongly associated with the humanities and interdisciplinary fields (Bronstein, 2007; Ellis & Oldman, 2005; Meho & Tibbo, 2003). Nearly all the respondents in one small study of interdisciplinary humanities and social science scholars engaged in some kind of browsing as part of their research process (Spanner, 2001). In the sciences, there appears to be more variation. For example, surveys have demonstrated that physicists, chemists and biologists identify up to half their reading material by browsing, but browsing among astronomers was considerably lower, at 20%, possibly due to the more comprehensive and integrated online information systems in the field (Tenopir et al., 2005).

Collections of various kinds lend themselves to browsing. Studies of humanities scholars and geographers have shown that library shelves are valued as a browsing environment, especially sections devoted to new books and journals (Borgman et al., 2005; Brockman et al., 2001). Women's studies scholars have relied heavily on browsing both publisher catalogs and bookstores, due in part to the less developed base of indexing and reference sources in newer interdisciplinary fields (Westbrook, 2003). Case studies of neuroscience research have demonstrated how the speed and flexibility of digital browsing can encourage review of material that might otherwise be ignored, such as compilations of conference poster abstracts that cover a multitude of very current research projects (Palmer, Cragin, & Hogan, 2007). Web browsing can also lead scholars to more conventional library resources that might not have been pursued through a library portal or gateway (Zainab, Huzaimah, & Ang, 2007). Moreover, table of contents browsing in journals has been readily adopted in the electronic environment, in conjunction with the follow-on activities of accessing and assessing, discussed further below (e.g., Eason & Harker, 2000; Eason, Yu, & Harker, 2000). More

specifically, studies have suggested that social scientists retrieve recent articles of interest through vertical chaining, moving from table of contents, to abstract, to full-text, while scientists browse journal titles and then perform vertical leaping, going directly to the full-text (Tenopir, 2003).

Among searching techniques, browsing is notable for its potential to result in serendipitous discovery. Because browsing tends to be broad and flexible, scholars encounter materials that would not be found through searching or chaining, and the new information may stimulate unexpected and fortuitous intellectual connections. A large survey of scholars in the United Kingdom showed that few scientists valued print collections for serendipitous browsing, but scholars in the arts, humanities, area studies and languages were twice as likely to consider it an essential aspect of browsing (Education for Change, 2002, p. 25). Interdisciplinary researchers have reported that physical libraries are more conducive to serendipitous discovery than digital libraries, and other scholars have reported that the ability to browse is a distinct benefit to having a library in close proximity (Borgman et al., 2005; Engel & Antell, 2004; Foster, 2004). In fact, some humanities scholars have reported that browsing is "difficult" to perform in the electronic environment (Buchanan et al., 2005).

Probing

For scholars seeking information across multiple domains, standard searching and browsing approaches can be inadequate due to the scatter of information and the disparity in vocabularies across fields (Mote, 1962; Weisgerber, 1993; White, 1996). Probing is an exploratory strategy used by interdisciplinary researchers to find relevant information that falls outside their discipline or area of expertise (Palmer, 2001b; Palmer & Neumann, 2002). Similar to browsing, probing may be loosely directed across a topic area, but it is distinct in its investigative nature and aim of identifying information in unfamiliar domains. It encompasses breadth exploration, identified by Foster (2004)—a "deliberate expansion of information horizons to bring within range different information types, sources, concepts, and disciplines" (p. 233). Not all probing is aimed at broadening or expanding the search scope, however. While researchers frequently probe into peripheral areas to increase their breadth of perspective and generate new ideas, probing in an outside field can also be deep and directed at solving a particular problem or locating a particular piece of missing information (Palmer, 1999b).

Cross-disciplinary searching and probing are not practiced exclusively by interdisciplinary researchers. Studies have documented the practice in various academic disciplines. Examples include molecular biologists conducting broad-based searches in databases to learn about unfamiliar areas and to stay current (Covi, 1999), and historians and music scholars searching for materials across a wide range of fields, including philosophy, anthropology, art history, literature, statistics, sociology, criminology and geography (C. D. Brown, 2002; Case, 1991). Domain-specific searching can also be "probing" in nature, especially when a research focus is not yet well defined

or understood. Studies of how domain knowledge is applied by users, or represented in search tools, have implications for the support of scholarly probing. For example, one study of humanities scholars suggested that domain knowledge improved success with conceptual searches, but subject classifications were not useful due to their misalignment with how scholars conceptualized their fields (Buchanan et al., 2005).

While much of the documented probing activity has been associated with exploratory database searching, interesting examples can also be found in studies of archival information work. A study of the research process of historians showed how they probe archival finding aids to discover unknown source material and to identify new keywords for expanding their base of searching (Duff & Johnson, 2002). This study also gave an account of interpersonal probing, in which the historian engaged the archivist in conversation and deliberately avoided the use of known keywords to better elicit additional terms. Probing far afield to identify keywords or find new information from an outside discipline can, of course, introduce terminology problems. "Translating," to construct search queries or to interpret content from an outside domain, is one of the cross-cutting primitives discussed below.

Accessing

Information service providers understand that providing "discovery is not enough;" scholars want direct access to the materials they identify (Bibliographic Services Task Force, 2005; Research Information Network, 2006). This expectation may be reflected in a recent report showing that over a three-year period scholars were increasingly less likely to view libraries as a gateway to information, with the trend markedly greater for the sciences and the social sciences compared to the humanities (Houseright & Schonfeld, 2008). Another suggestion of access needs can be seen in a study that showed how chemists at one institution "created and relied upon their own list of relevant e-journals" rather than using those created by the library, showing that personal tools "increase efficient connections to what they consider to be their core literature" (Davis, 2004, p. 331). When full-text digital library content is available, however, scholars across fields have exploited its efficiency and convenience (Barrett, 2005; Brockman et al., 2001; Eason, Richardson, & Yu, 2000; Hallmark, 2004).

The lower levels of production and distribution of digital sources is an important factor in lagging adoption in the humanities. In one large-scale survey, arts and humanities scholars were found to be three times as likely as medical, biological, and physical scientists to consider physical access to library collections essential to their research, and twice as likely as social scientists (Education for Change, 2002). Studies of humanities scholars have also demonstrated a continued reliance on primary materials held in special collections, archives and museums, coupled with regular travel to work on site with physical resources (Brockman et al., 2001; Case, 1991; Palmer, 2005; Palmer & Neumann, 2002; University of Minnesota Libraries, 2006; Wiberley, 2003).

In the sciences, e-journal use is dominant and strongly preferred over print (Hemminger et al., 2007; Tenopir et al., 2005). Some researchers save electronic copies for later access, but many studies have shown that scholars tend to print out articles or other sources for later reading (C. M. Brown, 1999; Eason & Harker, 2000; Eason, Richardson, & Yu, 2000; Murphy, 2003; Tenopir et al., 2005). For example, even though astronomers accessed about 80% of their readings from electronic sources, they printed out more than half on paper before reading, and less than one-fourth were read on a computer screen (Tenopir et al., 2005). That study found that HTML was favored for reading online and PDF format was preferred for printing. A "deep log analysis" of scholarly databases indicated that Blackwell Synergy users accessed documents in PDF twice as often as HTML, and Emerald Insight users accessed PDFs 56% of the time (Nicholas, Huntington, Jamali, & Watkinson, 2006). Another study reported that 70% of scholars surveyed preferred PDFs to HTML (Zainab et al., 2007). Print is still considered by many to have a distinct portability advantage, and improvements are needed in e-text functionality for backward and forward movement through pages within a document and between different documents (Institute for the Future, 2002).

Collecting

As researchers search for and access information, they build personal collections that support their current and long-term research. Gathering and organizing are the primitives associated with scholarly collecting of research materials. Unfortunately, only a few early studies have specifically examined the personal collecting behavior or scholars, and therefore there is limited understanding of patterns in content and use. The practice seems to be continuing over time with some variation due to e-resource availability. For example, studies ten years apart reported similar use of personal journal collections by medical and biological scientists for locating articles and keeping up with research in their field (Curtis, Weller, & Hurd, 1997; Kuruppu & Gruber, 2006). On the other hand, longitudinal surveys have tracked a decline in scientists' annual personal subscriptions, from an average of 5.8 titles in 1977 to 2.2 titles in 2002, with reliance on library collections increasing with the availability of e-journals (Tenopir et al., 2003; Tenopir et al., 2005).

As will be discussed briefly here and again more thoroughly in a later section on data sharing, reuse of data collections is a topic of great interest in LIS and is considered to be particularly important for data-intensive fields in the sciences. Personal scholarly collections, consisting primarily of documents rather than raw data, have also been perceived to have potential value for other users (Spanner, 2001), but there is little evidence of actual sharing practices. One study reported that one-third of fine arts respondents referred their students to resources in their own collections, because of its superiority and relevance over their university's collection (Reed & Tanner, 2001). Nearly half of the scholars in another survey felt that their personal collections would be of value to other researchers (University of Minnesota Libraries, 2006).

Gathering

Collections may be built due to a need for long-term accessibility, convenience or to support sustained work with a set of resources. An early, broad survey of humanities scholars, social scientists and scientists indicated that some sort of personal collection, consisting mostly of monographs and journals, was maintained by most respondents (Soper, 1976). A later study revealed similar gathering patterns, but showed that social scientists' collections were more likely to also include items such as bound reports, manuals and loose leaf materials (Case, 1986). The RLG studies reported on collections developed by academic departments tailored to disciplinary needs of their faculty that included materials such as monographs, journals, reports, prepublication papers, maps and photographs. More specifically, engineering labs often collected technical reports and linguistics departments collected significant dissertations in the field (Gould, 1988; Gould & Handler, 1989; Gould & Pierce, 1991).

Among humanities scholars and social scientists participating in a recent study, 37% claimed to have gathered unique research collections, and 56% reported engaging in "personal archiving activities" (University of Minnesota Libraries, 2006). Humanities scholars, in particular, have been shown to cultivate and take pride in their personal collections of books and other print sources (Brockman et al., 2001). Their collections "are a necessity since rereading is a significant part of their interpretive work. Any number of texts may require periodic or systematic reading, and some may be 'read' for years or decades" (Palmer, 2005, p. 1144). Scientists also gather collections of literature in the form of journals, conference proceedings, and individual photocopied and digital papers. Approximately 85 to 95% of the scientists surveyed in one study maintained collections of reprints and article copies, and 63% of chemists reported personal collections of over 500 reprints (C. M. Brown, 1999). In a more recent survey, 70% of faculty in science and medicine kept both print and electronic article collections (Hemminger et al., 2007). Scientists have reported the high value of being able to gather together large quantities of digital papers and have them mobile on their laptops (Palmer, 2005).

Scientists also collect the data they generate through experimentation and field studies, as well as data produced by other researchers for modeling purposes. In geography, for instance, collections of field notes are maintained, maps are collected in paper and digital forms and serve as both primary and reference resources, and "by mid-career, many have built substantial image collections of their own" (Borgman et al., 2005). With data becoming increasingly digital and more easily mobilized for other purposes, some researchers are becoming involved in data repository and federation efforts (Palmer, 2005), and some agencies are moving toward requirements for long-term data management plans for projects they fund.

Primary materials in the humanities are not generally generated by the researcher, but collected from a range of sources in the form of texts, images, facsimiles and artifacts. Other primary sources

frequently collected include manuscripts, letters, plays and photographs (University of Minnesota Libraries, 2006). The qualitative study of art historians, mentioned in the introduction, examined how researchers developed their own collections of art reproductions to "compensate for inaccessible or deficient institutional collections," and because they "have the advantage of being personally selected and indexed" (Bakewell et al., 1988, p. 19). Fine arts faculty collect books, videos, plays and musical scores (Reed & Tanner, 2001), and literary theorists prefer to purchase the books they analyze, rarely relying on borrowed copies (Covi, 1999). Historians' collections may be among the most diverse, since they rely heavily on their own data recorded in personal notebooks filled with annotations, facts and references, and collected cultural artifacts, such as items found in junk shops that relate to the time, place, or object of study (Case, 1991).

Organizing

Over time, personal collections become larger and more complex assemblages, and scholars devise organizational systems and tools for storing and managing the content. Accordingly, management of information was one of the activities proposed in Meho and Tibbo's (2003) extension of Ellis's model of scholarly information seeking discussed in the introduction. Most of the studies that have examined the organization of personal collections have been focused on the humanities or the social sciences. For example, despite the prevalence of digital materials, 98% of humanities and social science faculty in one university study reported keeping hard copies of print materials because of fear of computer failure, lack of technological skills, and computer storage space limitations (University of Minnesota Libraries, 2006). Much less is currently known about scientists' approaches to managing their collections of literature and data, possibly because organization is less of a concern or assumed to be more straightforward in the sciences.

Humanities scholars often develop personalized organizational systems for their collections. Arrangement and storage of materials may vary from piles on the floor to structured file folder systems and elaborate databases (Palmer & Neumann, 2002). As described in one study, a historical biographer captured each moment of the life of a person on individual 3x5 cards (Case, 1991). Art historians in another study developed custom approaches to organizing materials in accordance with their needs for both teaching and research, and expressed a need to develop more detailed cataloging systems (Bakewell et al., 1988). Reports have also demonstrated that scholars from various fields have been adopting citation management tools to assist with organizing digital content (Borgman et al., 2005; Brockman et al., 2001; C. M. Brown, 1999). At this point in time, scholars have recognized that the materials they collect have potential value to other researchers, but they consider their idiosyncratic organizational systems, as well as copyright restrictions, to be barriers to sharing (University of Minnesota Libraries, 2006). On the other hand, some scholars are creating highly sophisticated digital collections around their personal scholarly interests that are meant to be shared. For example, the thematic research collections being developed by humanities

scholars are scholarly products that that bring together specialized source material, tools and expertise to support inquiry in a specific research area (Palmer, 2004, 2005).

Reading

The act of reading is a highly ubiquitous information activity that has rarely been the direct object of study in information behavior research. Thus, surprisingly little is known about the variable and complex reading processes involved in research and scholarship. Aspects of scholarly reading have been reported as part of more general studies of document or e-journal use, with the primitives of scanning, assessing, and rereading emerging in the literature. When information is first encountered, it is scanned in some preliminary way, as when a scholar reviews bibliographic fields while searching the online catalog or segments of pages when flipping through of a volume in a library. Each source is assessed to determine its relevance to the information problem at hand or to a longer term information need, and these interactions differ based on the kind of source and the researcher's intentions and mode of inquiry. Other reading processes come into play when information is read more thoroughly or kept and reread later or over time.

General reading patterns related to e-journal use have been systematically documented in longitudinal surveys conducted by Tenopir and colleagues, showing differences among disciplines and important changes over time (e.g., Tenopir, 2003; Tenopir et al., 2003; Tenopir et al., 2005; Tenopir & King, 2008). Not surprisingly, e-journal use has become the norm in the sciences and mathematics, where the format has been widely available for some time and readily adopted. Strong levels of use have also been documented in business and economics, but history, education and the arts have made a slower transition, due at least in part to lower levels of e-journal availability in disciplines outside the sciences (Education for Change, 2002). Such e-resource trends are suggestive, but they are not direct measures of actual reading activities.

Scanning

Researchers often begin working with documents by scanning them prior to engaging in more thorough reading. This practice has always been common with print materials, and it is accelerating and becoming more dynamic in the digital environment. For example, studies have demonstrated that scientists and engineers tend to skim papers to identify key components, beginning with the abstract, then moving to section headings, lists, summary statements, definitions and illustrations (Schatz et al., 1999). This process has extended to digital documents, where search features make it easier to pinpoint segments for reading, such as descriptions of experimental techniques or application of theories (Bishop, 1999). In particular, more recent large-scale transaction log studies have suggested that scholars are making greater use of abstracts in full-text databases (Nicholas, Huntington, & Jamali, 2007). Analysis of ScienceDirect logs showed that social scientists conducted

the highest proportion of abstract-only sessions (41%), followed by mathematicians (40%), computer scientists (35%) economists (33%), life scientists (13%), engineers (13%), and chemists (12%). Supplementary surveys of users clarified that, while abstracts were valued for quick access and downloading, they did not substitute for reading the full article. Other studies have further confirmed that scholars often begin with preliminary parts of a document and then skim the full-text before printing for later reading (Tenopir et al., 2005).

The results from recent studies could be interpreted as evidence that scholars are reading more than in the past. For example, the number of articles read by university medical faculty was over 30% higher in 2006 than in the mid-1990s. At the same time, reading time per article fell, with medical scholars averaging about 24 minutes per article (Tenopir, 2006). However, while scholars are spending less time with more papers, they are also increasingly working through information on the Web by rapidly scanning material, or "bouncing" from site to site, a practice particularly common in medicine and the life sciences (Nicholas et al., 2006). Together these patterns suggest that researchers are not *reading* more, but rather scanning, exploring and getting exposure to more sources. In fact, they may be practicing active reading avoidance, as they quickly navigate through more material, spending less and less time with each item, attempting to assess and exploit content with as little actual reading as possible (Palmer, 2007; Renear, 2006, 2007).

Assessing

As researchers scan through documents quickly, sources of interest are assessed to determine their relevance and utility. This process of assessing has been described in number of ways—as differentiating, comparing and sifting—in previous studies (Ellis, 1993; Ellis et al., 1993; Foster, 2004; Unsworth, 2000). Bishop (1999) distinguished five separate stages of assessment, which can be distilled into these terms: "orientation" to form an initial impression of a work, "overview" to identify important details, "directing attention" to pinpoint specific document characteristics to skim, "comprehension" to interpret content, and "triggering" to initiate further reading (p. 265). Assessing is not always done item by item. Scholars have also been shown to assess aggregations of materials, such as issues of a journal or groups of sources that assist in keeping up-to-date with developments in their field of expertise (Bronstein, 2007).

A number of studies have focused on factors that influence a scholar's decision to obtain, read or otherwise use a particular source. Key criteria identified among studies include topicality, originality, perceived quality, timeliness, availability and peer review (Covi, 1999; Houghton, Steele, & Henty, 2004). In a unique longitudinal study of agricultural economists, these and additional features—orientation, depth, reading time and author and journal reputation—were important assessment factors in decisions in the eventual selection and use of materials from sets of search results (Wang & White, 1999). For historians working with archival materials, assessing has been found to involve understanding the context of a source and its relationships to other sources in a collection (Duff &

Johnson, 2002). As would be expected, book reviews are an important source of information for decisions about book purchases, according to a study of scholars across the arts, social sciences and sciences (Hartley, 2006).

Rereading

Books, articles, notes and documents of all kinds may be reread once or many times to recall content, increase comprehension and to relate and integrate previous research into a work in progress (e.g., Brockman et al., 2001; Palmer, 2005; Tenopir et al., 2005). By revisiting previously read material, scholars also build their baseline of information, identify gaps in their knowledge and develop new research directions (Foster, 2004). Rereading is one of the primary reasons that scholars build personal collections. For humanities scholars, rereading a work is a significant part of interpretation and analysis, and it may be a long-term undertaking over the course of a project, across multiple projects over time or over a career (Palmer & Neumann, 2002). In the sciences, astronomers were found to engage in more rereading activities than other scientists, "which may be due to the ease with which astronomers can retrieve older articles electronically, or they may re-read more because they reuse older articles more than other scientists" (Tenopir et al., 2005, p. 793).

Rereading is closely associated with writing. A study of interdisciplinary humanities scholars found that collected texts were used to "prime" for writing activities (Palmer & Neumann, 2002). Music scholars frequently reread sources throughout the writing-and-revision stages of a project (C. D. Brown, 2002), and literary critics reread their assembled primary and secondary research materials in order to develop writing strategies (Chu, 1999). On the other hand, for historians, considerable writing may be necessary during an initial reading, especially with primary sources that must be accessed in archives and special collections, compared to journals, which can be reread later at their "leisure" (Case, 1991, p. 74).

Writing

As with reading, writing is another core scholarly activity that has not been studied in depth as an information behavior. The act of assembling information in constructing new scholarly works is one writing primitive discussed in the literature. In addition, co-authoring and disseminating are distinct activities of interest in information research, with dissemination having a strong base of more general, relevant literature that has developed in the area of scholarly communication over a number of decades.

Differences in writing structure and style are apparent across disciplines and reflect scholars' approaches to formulating, articulating, organizing and presenting evidence within the research process (Cronin, 2003). "Writing is not just another aspect of what goes on in the disciplines, it is

seen as producing them"; each act of writing reconstructs and reinforces existing practices in a given field (Hyland, 2000, p. 3). A few studies have reported on levels of information use associated with writing processes. Scholars working in literary criticism were found to continue extensive information use throughout writing stages of a research project, while information searching tapers off to moderate or low levels (Chu, 1999). In a study of neuroscientists, both searching and reading were shown to continue during the writing phases in experimental and informatics projects, particularly to judge how to discuss new findings and claims in relation to existing literature (Palmer, Cragin, & Hogan, 2004).

Assembling

During the research process, scholars compose their thoughts through writing. Parts of texts are composed, integrated, revised and refined as the foundation of new publications. Ellis (1993) used the term "assembly" to denote the myriad of processes that are involved in drawing together ideas and results and writing them up for publication. Assembling is practiced in concert with searching, as well as reading, and extends well into the writing phases of a research project. Assembly by interdisciplinary scholars has been described as "picture building"—a set of behaviors scholars perform as they map out "in their minds, and on paper, the disciplines and concepts relevant to achieving an interdisciplinary overview of the topic" (Foster, 2004, p. 234). The cognitive and physical work of assembling a text can produce more than an image or sketch, however. It establishes the base for the scholarly product that will ultimately be disseminated.

For humanities scholars, assembling a text is formative and iterative work that involves continual information management, accretion, and refinement. For example, one study described how "each scholar had his or her own way of taking pieces of an idea or passages that were excised for editorial reasons and putting these into new files or documents to feed into new papers" (Brockman et al., 2001, p. 27; Palmer & Neumann, 2002). Literary scholars have been found to write in multiple stages, assembling their analysis into initial drafts followed by further writing and re-articulation before dissemination (Chu, 1999). Multiple, simultaneous processes were observed in the research projects of art historians, who gathered and organized materials as they analyzed sources and structured their own written arguments (Bakewell et al., 1988). Other structuring approaches can assist in assembly, such as with music scholars' creation of outlines, tables, lists, and chronologies early in the organizing stage of writing a research paper (C. D. Brown, 2002). Such non-narrative components appear to be especially influential in the sciences, where tables, diagrams and illustrations are a fundamental part of research communication (Hartley, 2006). Needless to say, word processing has altered assembly practices by simplifying integration, revision and formatting, and digital production has allowed for inclusion of multimedia content in assembled "texts."

Co-authoring

The practice of co-authorship has increased in recent decades, and its escalation in the sciences has been particularly controversial. Cronin and his colleagues have contributed a series of studies on authorship and other kinds of attribution, finding, for instance, that the incidence of co-authored articles in a selected psychology journal increased over 55% from the 1930s to the 1990s, likely due to more quantitative and experimental approaches in the field and the rise of modularized and discrete tasks in research teams. There was a striking increase in co-authorship in chemistry as well, rising from 44% to 99% over the course of the 20th century. In contrast, for philosophers—who tend to work independently with abstract issues and theories rather than with empirically based subjects, trends and data—only two percent of articles were co-authored in the 20th century (Cronin, Shaw, & La Barre, 2003, 2004).

The phenomenon of "hyperauthorship" has surfaced in recent years in fields such as high energy physics and biomedicine, where large distributed research projects are common and can produce, in extreme cases, papers assigning over one hundred authors (Biagioli, 2003; Cronin, 2001). However, many of the researchers listed as "authors" on these articles have played a role in the research but not participate in the actual writing of the paper (Cronin, 2001). Preparing a manuscript for publication has been shown to require effective collaboration, and as such, actual writing tends to be handled by a small group (Kim & Eklundh, 2001).

For those working in interdisciplinary fields, co-authorship can lead to significant information problems. Spanner (2001) found that differences in vocabularies made it difficult for research partners in computer science and biology to understand each other's contributions. Construction of a research report by collaborators required many hours on tasks including translating terminologies and negotiating sentence structure and overall format. Palmer (2001b) showed that interdisciplinary writing can be further complicated by the need to explain concepts to new audiences. As observed by Cronin (2001), even when researchers writing a joint paper share a common disciplinary background, scientific writing can result in a "pasteurized prose of collaboration." (p. 561).

Disseminating

Trends in open access tend to dominate much of the literature on dissemination of scholarly work, but there are other aspects of the dissemination process that have been studied empirically and are closely linked to the practice of research. For example, dissemination includes the work of evaluating appropriate journals and presses for submission of a manuscript and the act of presenting a paper and fielding follow-up questions at a conference. One project may spawn a number of scholarly products that emphasize different facets of the research or need to be crafted for different scholarly audiences or in variant formats. Extensive reshaping and rewriting is often

required by referees during the peer review process, and there may be moderate use of new information for these rewriting purposes (Chu, 1999).

Generalizations about the prominence of the journal article for scientific dissemination are well supported by research studies. Journal publishing has been documented as the major mode of dissemination in many fields of social sciences as well, with decisions about where to publish influenced by the standing of the journal in the field, followed by distribution and speed of publication, and audience to which the journal is addressed (Francis, 2005). Professional meetings are also considered essential dissemination routes, as seen in geography where "published information is too late" (Borgman et al., 2005, p. 647). Surprisingly, a study of music scholars found that conference proceedings were the most frequent mode of dissemination, followed by journal articles and then monographs (C. D. Brown, 2002). While more commonly associated with the humanities, books have been shown to be regularly produced in a range of fields, including psychology, linguistics and sociobiology (Varghese & Abraham, 2004). Books are prevalent in the humanities, but perhaps not as optimal as might be expected. A study of history, English and anthropology faculty at large research universities determined that, although departments expect monograph publication prior to consideration for tenure, the majority of faculty did not consider book-length texts necessary for representing or disseminating their scholarship (Estabrook, 2003).

Books can be particularly effective for broader circulation of ideas, however. They are more accessible for some audiences, providing an important means for presenting scientific knowledge to the general public, and they are especially important for the transfer of information across disciplinary boundaries (Palmer & Cragin, 2008). Dissemination of research •ndings to outside fields is challenging, since prestigious academic journals tend to be single subject publications and articles from outside the narrow focus are often rejected (McNicol, 2003). Therefore, scholars have difficulty determining where to publish interdisciplinary works and whether or not "journals outside ones' immediate field will count for tenure and promotion" (University of Minnesota Libraries, 2006, p. 22).

Levels of e-publishing have been rising along with the escalation of e-journal use. Although the sciences are generally associated with early advances in e-publishing, there is evidence that economists and computer scientists have been more reliant on the Web for disseminating information than scientists (Barjak, 2006). In the early RLG reports, psychology and chemistry scholars indicated that they preferred the longer peer-review process for disseminating articles rather than relying on preprint sources (Gould & Handler, 1989; Gould & Pierce, 1991). Since that time, faculty have developed more informed and positive perceptions of open-access and alternative models for publishing, but some scholars still perceive e-publishing to be risky and less rigorously reviewed. Studies have found that senior faculty tend to be more comfortable sharing early stages of work in online venues and that Web presentation and self-archiving is increasing across fields. For example, chemical engineering faculty have been shown to consider digital

alternatives highly viable, and some archaeologists are now willing to share field observations on open-access sites (Harley, Earl-Novell, Arter, Lawrence, & King, 2007).

As discussed by Kling and McKim (2000), "scholarly societies play a major role in the shaping of communications forums within a field, both because they are typically major publishers within a field, and also because they articulate and disseminate research and publishing standards for a field" (p. 1312). They note that both the American Chemical Society and the American Psychological Association have had policies directing authors not to put publications on the Web at any stage of production. A survey examining scientists' use of e-print archives for dissemination reported that they were used by a small number of psychology faculty and less so by chemists who indicated it was "against the policy of the publishers." Nearly one-quarter of psychology scholars also cited publisher policies as a reason for non-use of e-print archives (Lawal, 2002). The dialogue surrounding open access and the American Psychological Association's position on online distribution of scholarship has deepened over the years (Bullock, 2004; Brehm, 2007).

Some disciplines have long relied on pre-print servers for disseminating research results, the most renowned case being arXiv.org for physics, math, and computer science. Recently, the Consolidated Appropriations Act (2008) in the United States mandated that any research conducted on behalf of the National Institutes of Health must be made freely accessible, and other funding agencies like the National Science Foundation have been strong proponents of openly accessible research. Motivated in part by the rising cost of serials and the Web's influence on scholarship, many universities across the world are developing their own institutional repositories (IRs) to preserve and freely disseminate the work of their scholars. The use of IRs by faculty has been associated with self-archiving behavior (e.g., Kim, 2007; Xia & Sun, 2007). But while one international survey of over 1,200 scholars showed that nearly half of the respondents engaged in self-arching behavior (Swan & Brown, 2005), deposit in IRs has been slow in general. A range of factors have been identified, including faculty not understanding potential benefits and continued preference for traditional peer review venues over open access alternatives (Bell, Foster, & Gibbons, 2005; Crow, 2002; Palmer, Teffeau, & Newton, 2008; Park & Qin, 2007). At the same time, librarians and other proponents stress that IRs, author-pay models, and other open access options are "viable alternatives to the problem of unsustainable journal costs" (Harley et al., 2007, p. 8).

Collaborating

Research collaborations can range from two to hundreds of participants, as suggested by the hyperauthorship trends discussed above. They range along a "continuum" of engagement, from basic consultation to fully integrated teamwork, and project management may be loosely coordinated or highly structured and closely administered (Hara, Solomon, Kim, & Sonnenwald, 2003). Information exchange is a key component of successful collaboration (Haythornthwaite,

2006), as is support for administrative coordination and data storage and sharing, which are not yet sufficiently available to academic researchers, especially outside the sciences (University of Minnesota Libraries, 2006). The primitives of coordinating, networking and consulting are discussed, but data practices are covered later as a cross-cutting activity involved in collecting and collaborating.

It is worth noting that team based research is most commonly associated with the sciences, in part because there are clearer divisions of labor in scientific research than in the social sciences and humanities (Borgman, 2007). However, studies have not always indicated consistent differences along disciplinary lines. The RLG studies showed that collaboration was highly valued by history and literature scholars, as well as those in chemistry, engineering, and physics. At the same time, scholars in art history, philosophy, anthropology and psychology reported that they did not typically engage in collaborative work (Bakewell et al., 1988; Gould, 1988; Gould & Handler, 1989). However, results of co-authorship studies presented above indicated an escalation of collaboration in psychology.

Coordinating

Collaboration requires coordination of group work, which becomes more complicated as the number of institutional partners and the distance between them grows, as demonstrated in an analysis of projects conducted as part of an interdisciplinary program funded by the National Science Foundation (Cummings & Kiesler, 2005). Coordination problems experienced by scientists and engineers ranged from issues related to software differences across sites to difficulty with relatively simple tasks, such as scheduling meetings. Direct supervision was found to be the most effective coordination mechanism, and, as more institutions became involved in a project, workshops were effective for fostering joint efforts. Although employing more coordination mechanisms generally led to increased success, the study also found that large, multi-institutional projects tended to use fewer coordination procedures, suggesting that "the work arrangements that make these collaborations possible require a deliberate strategy for coordination" (Cummings & Kiesler, 2005, p. 717). McNicol (2003) likewise argued that clear leadership and coordination were vital to successful interdisciplinary work, and both formal and informal communication channels necessary for managing joint activity.

Early in a research project, collaborators need to define project boundaries and agree on "the doability of problems" to be addressed (Hara et al., 2003, p. 22). However, decisions on what work needs to be done, who is responsible for execution, and other details are also influenced by the structural, organizational and technological context and must be articulated and refined over the course of a project (Corbin & Strauss, 1993). Studies have suggested that socio-technical infrastructure can compensate, to some degree, for lack of physical proximity. Situation awareness, such as information about who has worked on what when, can be mediated by technology through

"contextual, task and process, and socio-emotional information" that facilitates collaboration across physical boundaries (Sonnenwald, Maglaughlin, & Whitton, 2004, p. 990). Innovations in collaborative technology appear to be having an impact on research production, as illustrated by one study of Australian researchers, which reported that approximately 60% of respondents felt new information environments and technologies had changed the way that they collaborated (Houghton et al., 2004).

Networking

Before a collaboration can begin, relationships with colleagues and associates need to be established; and for a collaboration to succeed, those relationships must be strengthened and maintained. Information technologies are making it easier for collaborators to communicate and work together and, of course, e-mail has been the lifeblood of communication among local and distant team members for many years (Walsh, Kucker, Maloney, & Gabbay, 2000). As would be expected, one study documented that collaborating scientists depended on Web-based communication more than those who work independently, and larger teams showed higher levels of use (Barjak, 2006). In an earlier comparative study, networked communication was associated with a dramatic increase in co-authored papers in math, a field known for independent scholarship. In addition, use of electronic mail, bulletin boards and listservs was found to be more common in mathematics and physics than in experimental biology or chemistry (Walsh & Bayma, 1996a, Walsh & Bayma, 1996b, p. 689).

Across one campus, humanities scholars and social scientists considered their colleagues to be everywhere, regardless of discipline, department, institution or even country (University of Minnesota Libraries, 2006). The traditional invisible college (Crane, 1972), or network for exchanging vital information in a research area, has become more of an "invisible constituency"—a heterogeneous, open and loosely organized network that serves more as ad hoc consultation than gatekeeping (Palmer, 2001b). New kinds of digital forums are now increasing engagement among researchers, resulting in online communities that foster collaborative research (Bibliographic Services Task Force, 2005). However, technology should not be considered the sole, or even primary, force producing these changes (Walsh & Bayma, 1996a, 1996b). Which technologies are chosen and how they are implemented is understood to be influenced by social and cultural factors specific to the research community (Hara et al., 2003), and therefore uneven adoption across scholarly communities is to be expected, as researchers gravitate to tools that fit the needs and practices of their collaborative groups.

Consulting

Scholars rely on consultation to assist with a number of scholarly activities. As discussed above, they contact colleagues and other experts for assistance in identifying information in the chaining process, and personal collections can function as a valuable consultative resource for other scholars. Researchers also regularly consult with each other to generate and test out ideas or to verify that they are following a productive and competitive research path. Consultation for stimulating and refining ideas has been observed in studies of scientific fields like molecular biology and neuroscience but also in music, history and the humanities more generally (C. D. Brown, 2002; Case, 1991; Covi, 1999; Palmer, 2005; Palmer et al., 2007). Historians who work primarily with archival materials consult about specific information sources, conferring with archivists as well as other researchers who have interacted with the materials being studied (Duff & Johnson, 2002; Palmer & Neumann, 2002).

In the networked information environment, scholars are more easily spanning geographic and intellectual space as they consult. The Web has been shown to foster short-term encounters with distant acquaintances or strangers that require little effort but have potentially high returns in access to valuable papers and bibliographies (Kuruppu & Gruber, 2006; Palmer, 2005). These associations are akin to what Cronin (2005) referred to as "cognitive partners," or the "unwitting, occasionally unseen, and not infrequently sidelined helpers" that support the scholarship of others (p. 110). In the humanities, the high level of dependence on these consultative relationships can "approach joint authorship" in terms of influence on a publication (Brockman et al., 2001, p. 11). For interdisciplinary humanities scholars, consulting with important scholars in outside areas may be necessary for translating ideas from one disciplinary context to another (Palmer & Neumann, 2002).

Cross-cutting primitives

Thus far we have focused on primitives that occur as scholars conduct information work related to a particular activity: searching, collecting, reading, writing or collaborating. Some primitives, however, naturally straddle or cut across two or more information work activities. In this section, we discuss four such cross-cutting primitives. The first three—monitoring, notetaking and translating—are of interest because of their significance in the research process but, unfortunately, there is a limited amount of research from which to draw conclusions. The fourth category, data practices, stands out from the others. It is not a primitive in its own right, but a set of activities around which a growing body of discourse and new research is emerging. The literature does not yet lend itself to identifying discrete primitives. However, it is an area of vital importance, due to the current emphasis on e-science and cyberinfrastructure in the information professions, and across fields where support for

digital scholarship is a concern for researchers, universities, funders and others with interests in advancing the research enterprise.

Monitoring

Although directed searching, chaining, browsing and probing all play integral roles in scholarly information-seeking, it is also useful for scholars to review new, relevant information on a regular basis. This type of monitoring behavior was defined by Ellis (1993) as "maintaining awareness of developments in a field through the monitoring of particular sources" (p. 482). Another study building on Ellis's work identified four types of monitoring differentiated by the type of source material (Bronstein, 2007). Monitoring electronic materials involves "performing a periodical literature search on abstracting and indexing databases, library catalogues, or Web sites to keep up-to-date with developments in the field." Monitoring printed materials involves "periodically looking for new book reviews, or looking through new journals issues." Networking consists of informal communication with colleagues in order to follow new developments in a research area. Finally, citation tracking is a "consequence of the different monitoring activities," and involves chaining activities or accessing other forms of referential materials to locate new sources. These forms of monitoring illustrate its cross-cutting nature: networking with colleagues and citation tracking, or chaining, are primitives associated with collaboration and searching activities, and reviewing journal issues may involve both browsing and scanning, primitives associated with searching and reading activities.

Humanities scholars and scientists have consistently reported frustration trying to keep up with information in their fields and the need for monitoring activities to stay current (Borgman et al., 2005; Brockman et al., 2001; C. D. Brown, 2002; Murphy, 2003; Tenopir et al., 2005). Reading journals received through personal subscriptions has been a traditional strategy (C. M. Brown, 1999), but, as indicated above, the rate of personal subscriptions has been decreasing in recent years. Nonetheless, studies continue to report that scanning new issues of journals is the most common way scholars monitor developments in their field (e.g., Francis, 2005; Vakkari & Talja, 2006), as newer Web-based services such as RSS feeds and citation alerting services are also being adopted.

As early as 2000, the SuperJournal Project showed that the majority of users valued alerting features (Eason, Yu, & Harker, 2000). Newer studies have documented increased use by of listservs, RSS feeds and other automated services by scientists (Hemminger et al., 2007). More specifically, Tenopir et al. (2005) found that many astronomers search current awareness resources online, but fewer used services such as the Astrophysical Journal (ApJ) Yellow Pages or emailed tables of contents. A study of scholars at a Malaysian university showed a preference for e-mail alerts linked directly to articles or table of contents of a particular journal (Zainab et al., 2007). Although there is less evidence of wide-scale adoption of alerting services in the humanities, one study indicated that

interdisciplinary humanities scholars favored "push services" such as subscriptions, listservs and mailings for keeping up with current trends in research (Palmer & Neumann, 2002).

Personal contacts are important sources of information for monitoring. The RLG studies showed that physicists, astronomers, computer scientists, political scientists and anthropologists relied on electronic communication and in-person meetings with colleagues to keep up with research developments (Gould & Handler, 1989; Gould & Pierce, 1991). Other approaches applied by social scientists and humanities scholars included attending scholarly conferences and colloquia, consulting book reviews and scholarly association newsletters, and reviewing preprints or reports of research in progress (Bakewell et al., 1988; Gould, 1988; Gould & Handler, 1989; Gould & Pierce, 1991). Westbrook (2003) found that women's studies scholars tracked the personal home pages of researchers known to them in the field. Currently, the online communities formed for collaborative purposes (discussed above) are a growing part of the repertoire of sources used in the monitoring strategies applied by scholars.

Notetaking

Discussions of writing practices have often focused on scholarly publishing, with little attention to how writing contributes throughout the scholarly production process. Above, we covered the primitive of assembling, in which notetaking is an important part of the writing done in preliminary stages of constructing a text. Notetaking is also a significant part of searching and reading, and in fact may be practiced together with any scholarly activity. Notes are produced systematically—on paper and online, in lab and field notebooks, and as part of data collection, experimentation and other more informal processes. Scientists record ideas, comments and procedures to accompany data, and scholars in all fields make annotations to articles they read and documents they write. Studies of annotation practices are informing the development of reading devices and writing software (e.g., Marshall, 1998; Marshall & Bernheim Brush, 2004; Schilit, Golovchinsky, & Price, 1998) and tools for assisting scholars in documenting their work with digital libraries and other online content (e.g., Bradley, 2008). In the Web environment, however, development of annotation systems needs to account for the fact that many individuals expect their notetaking to remain private and that there is a difference between "idealized memory" encoded in an annotation and its actual value (Marshall, 2005).

It has been noted that in the sciences, the "scribbling" and "jotting" of ideas and other informal writing that is performed at the bench may be a better representation of scientific work than the formal writing presented in research papers (Rheinberger, 2003). Notetaking is also widespread in the humanities, produced on all kinds of documents and in the course of managing all aspects of physical and intellectual scholarly work, from coordinating sources materials to generating original new texts (Brockman et al., 2001; Case, 1991; Toms & O'Brien, 2008). Studies have shown that literary scholars use mapping, sketching, and outlining for recording notes; historians develop

elaborate personal notetaking systems that emphasize chronology; and music scholars systematically capture explicit musical examples to be used in their written works (C. D. Brown, 2002; Case, 1991; Chu, 1999). Notetaking done in tandem with other writing tasks can be a largely tacit process that can produce large amounts of structured but informal text (O'Hara, Taylor, Newman, and Sellen, 2002). As discussed above in relation to assembly, when scholars take notes, they "are not just documenting their ideas. The act of writing is formative" (Palmer & Neumann, 2002, p. 100).

Translating

Scholarly work that crosses disciplinary boundaries poses a unique set of challenges. For scholars who are classically trained in a discipline, navigating the literature and research practices of another field requires developing familiarity with new terminology, concepts, theories and methods. For interdisciplinary collaborative groups in the sciences, translating is part of learning about collaborators' perspectives in relation to mutual research interests, and it is a necessary part of the communication required for making research progress (Palmer, 2001b). In the humanities, collaboration tends to be less formal in nature, but those involved in interdisciplinary scholarship still must translate as they work with sources and people outside their field and as they write for other disciplinary groups (Palmer & Neumann, 2002). In a study of environmental scientists, 89% of respondents indicated that they needed to be somewhat or very familiar with the terminology of another discipline in order to understand literature they were consulting (Murphy, 2003). Similarly, among a small sample of humanities and social science interdisciplinary scholars, the majority indicated that they needed to become familiar with the vocabularies of disciplines outside of their primary field in order to conduct successful research (Spanner, 2001). Additionally, literature written for other disciplinary audiences must be assessed for potential source bias (Meho & Tibbo, 2003).

Colleague networks are essential for making and maintaining the greater number of personal contacts needed to share and validate interdisciplinary information (Foster, 2004; Spanner, 2001). Interdisciplinary humanities scholars, in particular, may depend on local colleagues or outside experts for assistance interpreting ideas and written material encountered from other domains (Palmer & Neumann, 2002). The process of co-authorship is also complicated by the need for continual negotiations and decisions on what needs to be explained to different audiences, the work involved in refining and clarifying terminologies, and agreeing on acceptable reporting structures and formats for different fields (Palmer, 2001b; Spanner, 2001).

Data practices

The work of generating, managing and sharing data is an aspect of research that has received considerable attention in LIS and cognate areas, especially as academic libraries become more involved in curating and storing digital data for their constituencies. Librarians will increasingly take on responsibilities for the collection of both primary and secondary data and the processing, preservation and archiving required for sharing and reuse (Palmer & Cragin, 2008). In the sciences, research is becoming increasingly data intensive, and there are growing expectations that data resources will be aggregated and shared within and across disciplines. The collective management of data, however, does not fit with existing library models for managing other scholarly communication resources at the local or more global levels (Cragin & Shankar, 2006). Libraries have established infrastructure for acquiring, maintaining and providing access to many types of published materials, but they are not designed to accommodate the very different structures and uses of datasets.

Meeting data curation responsibilities will require a deep understanding of how researchers presently work with their data and of the potential of various kinds of data for future research. As with other types of information work, data practices are influenced by researchers' disciplines and subdisciplines and other organizational and collaborative arrangements. While it is apparent that varying practices need to be taken into account in the development of digital data collections, and the computing networks and information infrastructures in which they reside, the specific functions and roles of data as information resources are not yet well understood (Bowker, 2000; Hine, 2005). At the same time, the growth of digital data is clearly having a transformative effect on many sciences. For example, in experimental neuroscience the function of standard brain atlases has been extended as an organizational structure for bringing together digital materials on regions of the brain, and visualization of brain imaging data has fostered important new analytical approaches (Beaulieu, 2004).

Data repositories have been developed in fields where centralized data have been considered fundamental to the advancement of science, as in the case of GenBank and the Protein Data Bank (C. M. Brown, 2003). In some sciences it has become common practice to submit data as part of the peer review publishing process. While such practices are not yet widespread, concerns about managing and preserving digital data are growing across fields. A large-scale survey in the UK showed that computerized datasets were considered "essential" to the research work of scholars across a wide variety of fields (Education for Change, 2002). Not surprisingly, this was true for a higher percentage of scholars in medical and biological sciences (31%) and physical sciences and engineering (28%), but the social sciences (27%) were close behind, with a greater lag in the arts and humanities (14%) and area studies (12%). The results also indicated an increasing need to store, manipulate and communicate not just data but images, sounds and other media in fields as

diverse as astronomy, medicine and music. Interestingly, a recent study demonstrated that publications about cancer microarray clinical trials provided access to supplementary data were cited significantly more often than papers that did not provide data, a phenomenon that could be a strong motivator for scholars to use open data options in disseminating their research (Piwowar, Day, & Fridsma, 2007).

However, data sharing is a complex social process that involves collective interpretation of credibility and trust among researchers with different interests (Van House, Butler, & Schiff, 1998). Many fields have yet to develop the common practices needed for data sharing to succeed, in part because there may be no straightforward approach to gathering and coordinating data. For example, ecologists' locate data through multiple pathways, by making direct inquiries to museums, seeking referrals from other scientists, and searching for leads in peer-reviewed literature (Zimmerman, 2003). Reciprocity in data sharing and use is also uneven. Researchers whose work requires replication of experiments or draws heavily on observational data may be more interested in the mutual benefits associated with sharing, but many researchers will only work with their own data and are therefore less likely to make their data available for others (Borgman, 2007). Data sharing relationships can also productively guide how research is conducted, as was shown in a study of earthquake engineers and space physicists where experimentalists and modelers were found to be negotiating data sharing processes that satisfied all collaborators at early stages of a research project (Birnholtz & Bietz, 2003).

Researchers' views on the proper use of data are related to disciplinary norms for data collection and use. In one study, field researchers were found to be less flexible about editing data than researchers accustomed to using archival data (Leahey, Entwisle, & Einaudi, 2003). Interestingly, many of the concerns evident in the RLG studies are still at play. For example, psychologists noted that data collected for very specific experiments would be of little use to other researchers, and anthropologists expressed a proprietary attitude toward their own data that stemmed from the personal commitment that underscores ethnographic fieldwork (Gould & Handler, 1989). It is still the case that scientists wish to retain sole ownership when data is difficult to gather, and scholars who perform highly handcrafted and labor intensive data collection are also reluctant to disseminate data, at least until their results have been published (Borgman, 2007). As is the case in many fields, in ecology data sharing is not recognized as a scholarly contribution that counts toward promotion and tenure, and in some cases projects that reuse other scientists' data may not be considered legitimate research (Zimmerman, 2003). In general, since data practices within many domains tend to be "local, idiosyncratic, and oriented to current usage rather than preservation, curation, and access" (Borgman, 2007, p. 115), knowledge of current disciplinary practices is not sufficient for the work that will be required for libraries to integrate and archive data for the long term.

Conclusion

As indicated in the 2006 American Council of Learned Societies report, *Our Cultural Commonwealth*, providing the collections and tools needed for producing new scholarship is arguably the most important role for cyberinfrastructure and will require a digital resource base "that is developed for specific scholarly purposes" (p. 1). The literature presented here represents a wealth of research that as a whole builds a broad understanding of the scholarly information activities that this infrastructure needs to support across disciplines. More and more, scholars will be performing these activities online, and it follows that research library services will need to be an integral part of that digital work environment. In fact, academic and research libraries should expect that soon; in all but the most specialized cases, good service will be defined by scholars' ability to find and use the digital information they need for all stages of research.

The question facing service developers, then, is not what services need to be offered digitally, but rather how do we proceed in the long term to move all services to an e-research platform. A productive first step in developing a comprehensive set of development aims is to assess each of the identified scholarly information activities and their associated primitives in regard to these three questions:

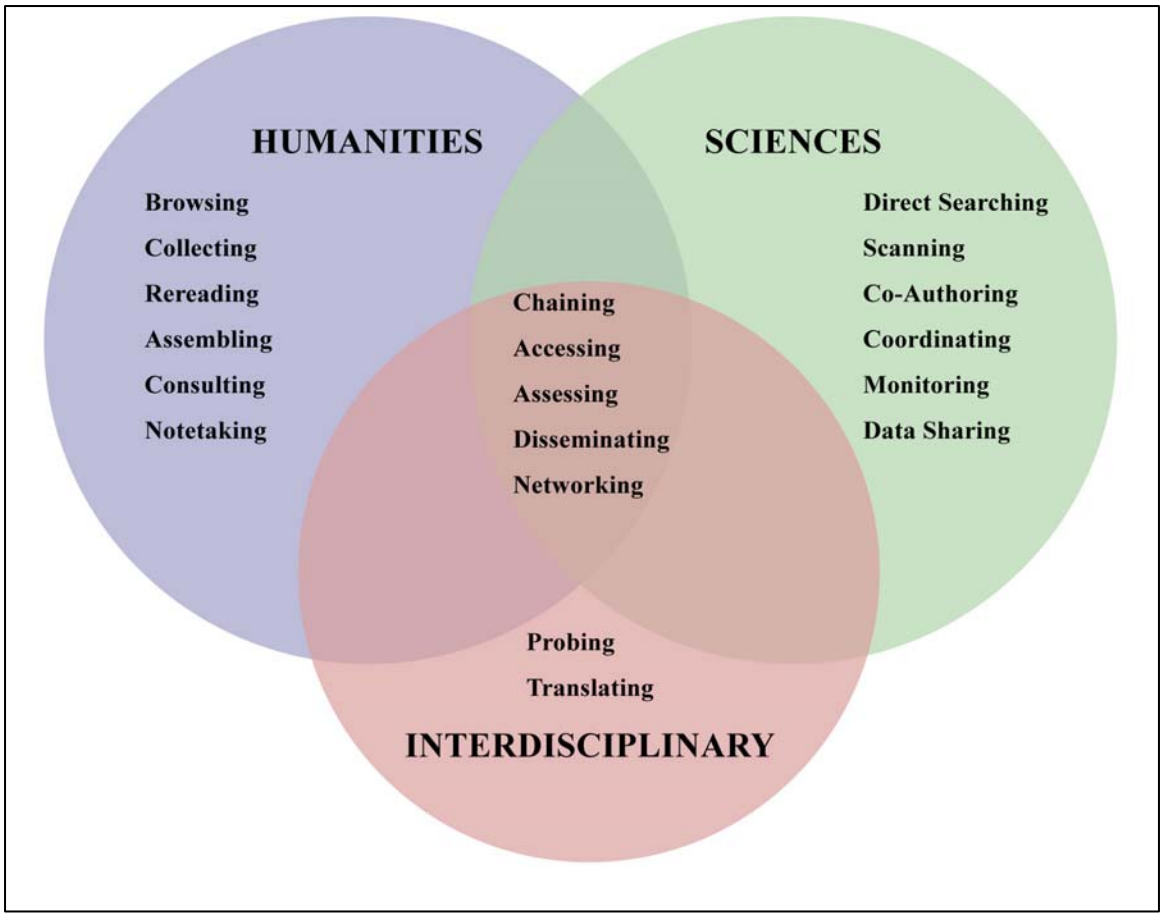
1. What resources and functions should be provided by research libraries?
2. What distinct disciplinary research practices need to be accommodated?
3. How should research, design, and development be prioritized within and across activities?

The literature discussed above begins to provide some answers to these questions. We know, for example, that scholars in every field engage in chaining activities to find resources, access and assess sources of information, network with others in their field, and actively disseminate their work. Studies of interdisciplinary scholars have also consistently shown the importance of probing and translating activities in research that crosses disciplinary boundaries. The findings also suggest that certain scholarly activities are more prevalent or more important in the humanities or in the sciences. Trends among social scientists are more difficult to discern in the literature, but some generalizations can be made in terms of how their modes of inquiry align approaches applied in the humanities and sciences. Some social scientists, particularly those doing historical and cultural interpretations, are more akin to humanists whose information paths are long, mutable and

centrifugal in nature. Quantitative social scientists are more similar to scientists who have more segmented, directed and centripetal information gathering patterns (Palmer, 2005, p. 1145).

Thus, humanities scholars and other researchers deeply engaged in interpreting source material rely heavily on browsing, collecting, rereading and notetaking. They tend to compile a wide variety of sources and work with them by assembling, organizing, reading, analyzing and writing. In interacting with colleagues, they typically consult rather than collaborate, with the notion of the lone scholar persisting in certain fields. On the other hand, scientists and others who test conjectures or solve problems with data they generate tend to place more importance on direct searching, monitoring, and scanning activities. Collaboration is common, resulting in a high level of co-authoring and the need to coordinate activities among the research team. Developments in cyberinfrastructure and distributed computer networks have also spurred data sharing activities within and among research communities in these fields. The figure below illustrates the role of these scholarly primitives in these broad disciplinary areas. A table showing a more elaborated interpretation of the frequency and importance of the various scholarly activities in the humanities and the sciences is presented in the appendix.

Figure 1: Scholarly primitives associated with disciplinary approach



To further our analysis in terms of how academic libraries can support research practices, below we have mapped scholarly activities to a sampling of recommendations found in the literature and to other common library services. The table makes explicit the relationship between existing or emerging services offered by individual libraries and the activities of scholars, highlighting those that might be best implemented as cooperative or shared services developed via cloud computing or managed through consortial arrangements to achieve economies of scale.

The table separates bibliographic services and collection development efforts from other types of library services. These distinctions create clusters of recommendations for certain scholarly activities and gaps for others. For example, bibliographic services are poised to continue to support or augment searching, reading, and the cross-cutting activities, while collecting, writing, and collaborating appear disconnected from bibliographic advances. Additionally, collection development is strongly associated with accessing materials, and libraries investing in foundational reference materials will support interdisciplinary primitives like probing and translating, but support for other activities is limited. Rereading has a notable lack of corresponding services, presumably because of the individualized nature of the activity.

Table 3: Scholarly primitives and corresponding library services

Highlighted cells indicate potential collaborative or shared services.

Scholarly Primitives	Type of Library Services		
	Bibliographic Services	**Collection Development**	**Other Services**
Searching			
Direct searching	Full-text searching[1]; Customized searching over broad array of resources[1]; Exposure of metadata to external search engines[1]; Enriched metadata (e.g., abstracts for chapters in edited volumes)[1,7]; Comprehensive cataloging / indexing of archival materials[2]		Library research instruction; Finding aid development
	Automatically generated suggestions for failed searches[1]; Subject-specific search engines[7]; Improved discovery for foreign language materials[7]		

Scholarly Primitives	Type of Library Services		
	Bibliographic Services	**Collection Development**	**Other Services**
Chaining	FRBR based navigation of results[1] and faceted browsing		
Browsing	Recommender functionality[1]; FRBR based navigation of results sets and faceted browsing[1]	Digital "bookshelves" for new acquisitions	Tools for browsing and exploring sets of e-texts[4]
Probing	Sensitivity to abstruse scholarly terms[1]	Digital reference materials across fields	
Accessing	Direct access to content whenever possible[1]; Expanded access and delivery[1,5,6]	Digital backfiles of non-scientific serials; Digitization of archival and rare materials[2]; Digitization of foreign language materials[7] Provide access to scholars' thematic research collections[3]; Literature-based discovery tools and aggregations[3]	Interlibrary loan and document delivery[2,5] Language translation services for non-specialists (e.g., business, management)[7]

Scholarly Primitives	Type of Library Services		
	Bibliographic Services	**Collection Development**	**Other Services**
Collecting			
Gathering	Tools for saving and exporting results sets	Curation of scholarly thematic research collections[3]	Clearinghouse for tools for collection, storage, and sharing resources[2]
Organizing		Cataloging of scholarly thematic research collections[3]	Software support: bibliographic (Endnote, Refworks), productivity, information management
			Support for downloading, storing, and organizing e-texts[4]
Reading			
Scanning	Results sorting by format, granularity, and facets[1]		Tools for scanning and exploration of a e-texts or set of e-texts[4]
Assessing	Recommender features for results sets[1]; Relevance rankings for results sets[1]		
Rereading			

Scholarly Primitives	Type of Library Services		
	Bibliographic Services	Collection Development	Other Services
Writing			
Assembling			Support for data analysis software and techniques; Tools to facilitate encoding of e-text in markup languages[4,6]
Co-authoring			Intellectual property support
			Tools to foster collaboration across insitutions[2]; Tools to support document reviewing[2]
Disseminating		Repository tools to facilitate selection and ingest of scholarly products	Intellectual property support; Bibliographic instruction
Collaborating			
Coordinating			Tools for collaboration across insitutions[2]
Networking			Social networking techniques for identifying collaborators/competitors

Scholarly Primitives	Type of Library Services		
	Bibliographic Services	**Collection Development**	**Other Services**
Consulting			Tools to foster collaboration across insitutions[2]; Tools to support document reviewing[2]
Cross-cutting			
Monitoring	Push-services for new acquisitions	Digital "bookshelves" for new acquisitions	Push-services for new acquisitions
Notetaking	Expose curated annotations to search engines	Curate annotations of scholarly work	Notetaking tools for creation, editing, and saving notes and annotations[4]; Tools for encoding of e-text in markup languages[4,6]
Translating	Sensitivity to abstruse scholarly terms[1]	Digital reference materials across fields	
Data Sharing	Searching across curated databases, include variable names as access points	Database and repository tools for data curation	Support for collecting, preserving, and sharing data

[1] Bibliographic Services Taskforce (2005)
[2] University of Minnesota Libraries (2006)
[3] Palmer (2004, 2005)
[4] Toms & O'Brien (2008)
[5] Education for Change (2002)
[6] Brockman et al. (2001)
[7] Research Information Network (2006)

Many of the services listed above are already provided at some institutions, but it is unlikely prioritization of services and allocation of resources has been based on a full assessment of the scholarly activities that need support, and available and attainable technologies. Opportunities for development are continually presenting themselves, while many longstanding challenges remain. It is interesting to note that the Education for Change (2002) project reported a prominent pattern across disciplines: "*finding* information electronically was the easiest to do; *accessing* the information was more difficult and *using* it more difficult still" (p. 8). This sequencing is consistent with the tenor of results covered in this review. Searching is becoming more fluid, and scholarly information of all kinds is increasingly accessible as more content makes its way to the Web. The remaining activities of collecting, reading, writing and collaborating, and especially the cross-cutting primitives, are much more sparsely supported online and often only as a byproduct of existing systems rather than as a deliberately designed feature. Moreover, these functions have received much less direct attention by researchers than searching behavior and search system capabilities.

The findings covered in this report suggest many possible development directions and some important broad disciplinary distinctions. Taking the collecting activity as an example, we can observe that scholars collect through chaining, and they chain through documents, web resources of all kinds, and people. In the humanities, personal collections are the equivalent of finely curated special collections that have been expertly selected and controlled for quality and application. Rereading and notetaking are core functions with these collections. There is considerable potential for sharing and reuse of these collections, but the provenance and context of the materials from the scholar's research perspective is a large part of the value that would need to be retained and represented. In the sciences, the processes and reasons for building personal collections are very different. Perhaps most importantly, datasets are a large part of personal information management, and while datasets are beginning to be made available online for "collecting," we have yet to learn how to support dataset chaining for discovery. Scientists' collections of PDF papers may well be selected, at least in part, through their "horizontal" searching and reading process, which seems to be aimed at *not* reading. Thus, if scientists are collecting through a process of elimination, rather than one of accretion, perhaps an activity quite different than chaining should be fostered.

The specific results enumerated here offer much needed detail on behaviors and aims of scholars in their information work that suggest a range of development requirements and goals. **In determining priorities for development, there are two kinds of service contributions that seem most worthy of investment:**

1. services that are most likely to actually advance the conduct of research, either by simplifying difficult tasks or by supporting new kinds of analysis with digital content; and

2. services that provide economies of scale across institutions, disciplines or genres of information.

Research libraries are well positioned to play a key role in improving the information environment for scholarly work, but they will need to make hard choices about what to do and what not to do for the communities they serve, and then they will need to make a serious commitment to sustained development fully informed by research on scholarly information work.

Appendix

The following table represents a rough estimate of the frequency and importance of scholarly activities in the sciences and humanities, based on the literature covered in this report. It is important to note that some of the distinctions made in the table directly relate to research findings; in other cases, extrapolations have been drawn from the discussion provided in the papers reviewed. The table is meant to be a starting point for additional research, not a definitive assessment. Probing and translating activities are not included since they are unique in their strong association with interdisciplinary scholars and scientists.

Table A-1: Frequency and importance of scholarly primitives by domain

Scholarly Primitives	Sciences		Humanities		Notes
	Frequency	Importance	Frequency	Importance	
Writing					
Assembling	Medium	Medium	High	High	Inclusion of non-narrative components (e.g., tables, diagrams) important for scientists. Humanists' interpretive work often draws on variety of primary/secondary sources.
Co-authoring	High	High	Low	Low	Co-authoring is the norm for scientific fields. Notion of solitary humanities scholar continues but is lessening with advances in collaborative technology. Co-authoring is complex for those working in interdisciplinary fields due to terminology and research approaches.
Disseminating	High	High	Low	High	In sciences, journal articles are primary means of dissemination; usage of preprint archives as venue for dissemination is increasing. In humanities, monographs are still common for scholarly output. Across all fields, dissemination is essential for gaining tenure.
Collaborating					
Coordinating	High	High	Low	Low	In the sciences, becomes more complex as number of institutional partners increases.
Networking	High	High	Medium	High	Scientists frequently use web based communication, especially when working with large research teams. In the humanities, a combination of the traditional invisible college and new digital forums are used for information exchange.
Consulting	Medium	Medium	Medium	High	Humanists rely on consultation for motivation, idea generation, feedback, and potential sources. In the sciences, preprint exchange is common in some fields. Consulting is particularly important for interdisciplinary scholars as they "translate" ideas from one disciplinary context to another.

Scholarly Primitives	Sciences		Humanities		Notes
	Frequency	Importance	Frequency	Importance	
Cross-cutting					
Monitoring	High	High	Low	Medium	Scanning new journal issues is common practice in both sciences and humanities; personal contacts are also important in both fields. Use of RSS feeds and citation alerts becoming more widespread in sciences, with lower use in the humanities.
Notetaking	Medium	Medium	High	High	In the sciences, may be an aspect of data collection during experiments and results interpretation. In humanities, it is essential for engagement with texts and supports the writing process.
Data Sharing	High	High	Low	Low	Scientific research is increasingly data intensive; data repositories are becoming more common. In the humanities, research data is idiosyncratic and may have intellectual property concerns because of primary texts (books, images, etc.).

Bibliography

American Council of Learned Societies. (2006). Our cultural commonwealth: *The report of the American Council of Learned Societies Commission on cyberinfrastructure for the humanities and social sciences*. New York: American Council of Learned Societies. Retrieved July 8, 2008, from http://www.acls.org/cyberinfrastructure/OurCulturalCommonwealth.pdf

Bakewell, E., Beeman, W. O., & Reese, C. M. (1988). *Object, image, inquiry: The art historian at work*. Santa Monica, CA: J. Paul Getty Trust.

Barjak, F. (2006). The role of the internet in informal scholarly communication. *Journal of the American Society for Information Science and Technology, 57*(10), 1350-1367.

Barrett, A. (2005). The information-seeking habits of graduate student researchers in the humanities. *The Journal of Academic Librarianship, 31*(4), 324-331.

Bates, M. J. (1994). The design of databases and other information resources for humanities scholars: The Getty online searching project report no. 4. *Online & CDROM Review*, *18*(6), 331-340.

Bates, M. J. (1996a). The Getty end-user online searching project in the humanities: Report no. 6: Overview and conclusions. *College and Research Libraries, 57*(6), 514- 523.

Bates, M. J. (1996b). Learning about the information seeking of interdisciplinary scholars and students. *Library Trends*, *45*(2), 155-164.

Bates, M. J. (2002). Speculations on browsing, directed searching, and linking in relation to the Bradford distribution. In H. Bruce, R. Fidel, P. Ingwersen, & P. Vakkari (Eds.), *Emerging frameworks and methods: Proceedings of the Fourth International Conference on Conceptions of Library and Information Science* (CoLIS 4), (pp. 137-150). Greenwood Village, CO: Libraries Unlimited.

Bates, M. J. (2007). What is browsing—really? A model drawing from behavioural science research. *Information Research, 12*(4), Retrieved May 30, 2008, from http://InformationR.net/ir/12-4/paper330.html

Bates, M. J., Wilde, D. N., & Siegfried, S. (1995). Research practices of humanities scholars in an online environment: The Getty online searching project report no. 3. *Library & Information Science Research, 17*(1), 5-40.

Beaulieu, A. (2004). From brainbank to database: The informational turn in the study of the brain. *Studies in History and Philosophy of Biological and Biomedical Sciences, 35*(2), 367– 390.

Bell, S., Foster, N. F., & Gibbons, S. (2005). Reference librarians and the success of institutional repositories. *Reference Services Review, 33*(3), 283-290.

Biagioli, M. (2003). Rights or rewards?: Changing frameworks of scientific authorship. In Biagioli, M. & Galison, P. (Eds.), *Scientific authorship: Credit and intellectual property in science* (pp. 253-279). New York: Routledge.

Bibliographic Services Task Force. (2005). *Rethinking how we provide bibliographic services for the University of California*. CA: The University of California Libraries. Retrieved on August 15, 2008 from http://libraries.universityofcalifornia.edu/sopag/BSTF/Final.pdf

Birnholtz, J. P., & Bietz, M. J. (2003). Data at work: Supporting sharing in science and engineering. *Proceedings of the 2003 International ACM SIGGROUP Conference on Supporting Group Work*, 339-348.

Bishop, A. P. (1999). Document structure and digital libraries: How researchers mobilize information in journal articles. *Information Processing and Management, 35*(3), 255-279.

Borgman, C. L. (2000). Digital libraries and the continuum of scholarly communication. *Journal of Documentation, 56*(4), 412-430.

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

Borgman, C. L., Smart, L. J., Millwood, K. A., Finley, J. R., Champeny, L., Gilliland, A. J., et al. (2005). Comparing faculty information seeking in teaching and research: Implications for the design of digital libraries. *Journal of the American Society for Information Science and Technology, 56*(6), 636-657.

Bowker, G. C. (2000). Biodiversity datadiversity. *Social Studies of Science, 30*(5), 643-683.

Bradley, J. (2008). Pliny: A model for digital support of scholarship. *Journal of Digital Information, 9*(26). Retrieved December 14, 2008, from http://journals.tdl.org/jodi/article/view/209/198

Brehm, S. S. (2007). Open access: A thorny debate. *Monitor on Psychology, 38*(8). Retrieved September 12, 2008 from http://www.apa.org/monitor/sep07/pc.html

Brockman, W. S., Neumann, L., Palmer, C. L., & Tidline, T. J. (2001). *Scholarly work in the humanities and the evolving information environment.* Washington, DC: Digital Library Federation and the Council on Library and Information Resources. Retrieved March 24, 2008, from http://www.clir.org/pubs/reports/pub104/pub104.pdf

Bronstein, J. (2007). The role of the research phase in information seeking behaviour of Jewish studies scholars: A modification of Ellis's behavioural characteristics. *Information Research, 12*(3), Retrieved March 25, 2008, from http://informationr.net/ir/12-3/paper318.html

Brown, C. D. (2002). Straddling the humanities and social sciences: The research process of music scholars. *Library & Information Science Research, 24*(1), 73-94.

Brown, C. M. (1999). Information seeking behavior of scientists in the electronic information age: Astronomers, chemists, mathematicians, and physicists. *Journal of the American Society for Information Science, 50*(10), 929-943.

Brown, C. M. (2003). The changing face of scientific discourse: Analysis of genomic and proteomic database usage and acceptance. *Journal of the American Society for Information Science and Technology, 54*(10), 926-938.

Buchanan, G., Cunningham, S. J., Blandford, A., Rimmer, J., & Warwick, C. (2005). Information seeking by humanities scholars. In A. Rauber, S. Christodoulakis, & A M. Tjoa (Eds.) *Research and advanced technology for digital libraries: Proceedings from the 9th European conference, ECDL 2005, Vienna, Austria, September 18-23, 2005* (pp. 218-229). Berlin: Springer.

Bullock, M. (2004). What is open access? *Psychological Science Agenda, 18*(11). Retrieved July 2, 2008 from http://www.apa.org/science/psa/nov4openacprnt.html

Case, D. O. (1986). Collection and organization of written information by social scientists and humanists: A review and exploratory study. *Journal of Information Science, 12*(3), 97-104.

Case, D. O. (1991). The collection and use of information by some American historians: A study of motives and methods. *The Library Quarterly, 61*(1), 61-82.

Chang, S.-J., & Rice, R. E. (1993). Browsing: A multidimensional framework. *Annual Review of Information Science and Technology, 28*, 231-276.

Chu, C. M. (1999). Literary critics at work and their information needs: A research-phases model. *Library and Information Science Research, 21*(2), 247-273.

Consolidated Appropriations Act of 2008. (2008). H.R. 2764, 110th Congress § 218.

Corbin, J. M., & Strauss, A. L. (1993). The articulation of work through interaction. The *Sociological Quarterly, 34*(1), 71-83.

Courtright, C. (2007). Context in information behavior research. *Annual Review of Information Science and Technology, 41*, 273-306.

Covi, L. M. (1999). Material mastery: Situating digital library use in university research practices. *Information Processing and Management, 35*(3), 293-316.

Cragin, M. H., & Shankar, K. (2006). Scientific data collections and distributed collective practice. *Computer Supported Cooperative Work: The Journal of Collaborative Computing, 15*(2-3), 185-204.

Crane, D. (1972). *Invisible colleges: Diffusion of knowledge in scientific communities*. Chicago: University of Chicago Press.

Cronin, B. (2001). Hyperauthorship: A postmodern perversion or evidence of a structural shift in scholarly communication practices? *Journal of the American Society for Information Science and Technology, 52*(7), 558-569.

Cronin, B. (2003). Scholarly communication and epistemic cultures. *The New Review of Academic Librarianship, 9*(1), 1-24.

Cronin, B. (2005). *The hand of science: Academic writing and its rewards*. Latham, MD: Scarecrow Press.

Cronin, B., Shaw, D., & La Barre, K. (2003). A cast of thousands: Coauthorship and subauthorship collaboration in the 20th century as manifested in the scholarly journal literature of psychology and philosophy. *Journal of the American Society for Information Science and Technology, 54*(9), 855-871.

Cronin, B., Shaw, D., & La Barre, K. (2004). Visible, less visible, and invisible work: Patterns of collaboration in 20th century chemistry. *Journal of the American Society for Information Science and Technology, 55*(2), 160-168.

Crow, R. (2002). *The case for institutional repositories: A SPARC position paper*. Washington, DC: The Scholarly Publishing and Academic Resources Coalition. Retrieved May 30, 2008, from http://hdl.handle.net/2027/spo.3336451.0011.111

Cummings, J. N., & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. *Social Studies of Science, 35*(5), 703-722.

Curtis, K. L., Weller, A. C., & Hurd, J. M. (1997). Information-seeking behavior of health sciences faculty: The impact of new information technologies. *Bulletin of the Medical Library Association, 85*(4), 402-410.

Davis, P. M. (2004). Information-seeking behavior of chemists: A transaction log analysis of referral URLs. *Journal of the American Society for Information Science and Technology, 55*(4), 326-332.

Duff, W. M., & Johnson, C. A. (2002). Accidentally found on purpose: Information-seeking behavior of historians in archives. *Library Quarterly, 72*(4), 472-496.

Eason, K., & Harker, S. (2000). Psychological processes in the use of electronic journals. *Serials, 13*(2), 67-72.

Eason, K., Richardson, S., & Yu, L. (2000). Patterns of use of electronic journals. *Journal of Documentation, 56*(5), 477-504.

Eason, K., Yu, L., & Harker, S. (2000). The use and usefulness of functions in electronic journals: The experience of the SuperJournal Project. *Program, 34*(1), 1-28.

Education for Change Ltd., SIRU at the University of Brighton, and The Research Partnership. (2002). *Researchers' use of libraries and other information sources: Current patterns and future trends.* London: Higher Education Funding Council for England. Retrieved August 12, 2008 from http://www.rslg.ac.uk/research/libuse/LUrep1.pdf

Egan, M. E. (Ed.). (1954). *The communication of specialized information*. Chicago: American Library Association for the University of Chicago Graduate Library School.

Ellis, D. (1989). A behavioral approach to information retrieval system design. *Journal of Documentation, 45*(2), 171-212.

Ellis, D. (1993). Modeling the information-seeking patterns of academic researchers: A grounded theory approach. *The Library Quarterly, 63*(4), 469-486.

Ellis, D., Cox, D., & Hall, K. (1993). A comparison of the information seeking patterns of researchers in the physical and social sciences. *Journal of Documentation, 49*(4), 356-369.

Ellis, D., & Oldman, H. (2005). The English literature researcher in the age of the Internet. *Journal of Information Science, 31*(1), 29-36.

Engel, D., & Antell, K. (2004). The life of the mind: A study of faculty spaces in academic libraries. *College & Research Libraries, 65*(1), 8-26.

Estabrook, L. (2003). *The book as the gold standard for tenure and promotion in the humanistic disciplines*. Report for the Committee on Institutional Cooperation. Retrieved July 10, 2008, from http://www.cic.net/Libraries/Reports/ScholarlyCommunicationsSummitReport_Dec03.sflb

Evans, J. (2008). Electronic publication and the narrowing of science and scholarship. *Science, 321*(5887), 395-399. Retrieved on September 12, 2008, from http://www.sciencemag.org/cgi/content/full/sci;321/5887/395

Foster, A. (2004). A nonlinear model of information-seeking behavior. *Journal of the American Society for Information Science and Technology, 55*(3), 228-237.

Francis, H. (2005). The information-seeking behavior of social science faculty at the University of the West Indies, St. Augustine Campus. *Journal of Academic Librarianship, 31*(1), 67-72.

Galison, P. (1996). Computer simulations and the trading zone. In P. Galison, & D. Stump (Eds.), *The disunity of science: Boundaries, contexts, and power* (pp. 118-157). Stanford: Stanford University Press.

Gould, C. C. (1988). *Information needs in the humanities: An assessment: Prepared for the Program for Research Information Management of the Research Libraries Group, Inc.* Stanford, CA: Research Libraries Group.

Gould, C. C., & Handler, M. (1989). *Information needs in the social sciences: An assessment: Prepared for the Program for Research Information Management of the Research Libraries Group, Inc.* Mountain View, CA: Research Libraries Group.

Gould, C. C., & Pearce, K. (1991). *Information needs in the sciences: An assessment: Prepared for the Program for Research Information Management, the Research Libraries Group, Inc.* Mountain View, CA: Research Libraries Group.

Green, R. (2000). Locating sources in humanities scholarship: The efficacy of following bibliographic references. *The Library Quarterly, 70*(2), 201-229.

Hallmark, J. (2004). Access and retrieval of recent journal articles: A comparative study of chemists and geoscientists. *Issues in Science and Technology Librarianship, 40*, Retrieved March 25, 2008, from http://www.istl.org/04-summer/article1.html

Hara, N., Solomon, P., Kim, S., & Sonnenwald, D. (2003). An emerging view of scientific collaboration: Scientists' perspectives on collaboration and factors that impact collaboration. *Journal of the American Society for Information Science and Technology, 54*(10), 952-965.

Harley, D., Earl-Novell, S., Arter, J., Lawrence, S., & King, C. J. (2007). The influence of academic values on scholarly publication and communication practices. *Journal of Electronic Publishing, 10*(2), Retrieved April 2, 2008, from http://hdl.handle.net/2027/spo.3336451.0010.204

Hartley, J. (2006). Reading and writing book reviews across the disciplines. *Journal of the American Society for Information Science and Technology,* 57(9), 1194-1207.

Haythornthwaite, C. (2006). Learning and knowledge networks in interdisciplinary collaborations. *Journal of the American Society for Information Science and Technology, 57*(8), 1079-1092.

Hemminger, B. M., Lu, D., Vaughan, K. T. L., & Adams, S. J. (2007). Information seeking behavior of academic scientists. *Journal of the American Society for Information Science and Technology, 58*(14), 2205-2225.

Hine, C. (2005). Material culture and the shaping of e-science. *First International Conference on e-Social Science*, June 22-24, Manchester, UK. Retrieved May 30, 2008, from http://www.ncess.ac.uk/events/conference/2005/papers/papers/ncess2005_paper_Hine.pdf

Hjørland, B., & Albrechtsen, H. (1995). Toward a new horizon in information science: Domain-analysis. *Journal of the American Society for Information Science, 46*(6), 400-425.

Houghton, J. W., Steele, C., & Henty, M. (2004). Research practices and scholarly communication in the digital environment. *Learned Publishing, 17*(3), 231-249.

Housewright, R., & Schonfeld, R. (2008). *Ithaka's 2006 studies of key stakeholders in the digital transformation in higher education*. New York: Ithaka. Retrieved on September 12, 2008, from http://www.ithaka.org/research/faculty-and-librarian-surveys

Hyland, K. (2000). *Disciplinary discourses: Social interactions in academic writing*. Essex: Pearson Education Limited.

Ileperuma, S. (2002). Information gathering behaviour of arts scholars in Sri Lankan universities: A critical evaluation. *Collection Building, 21*(1), 22-31.

Institute for the Future. (2002). *Final synthesis report of the e-journal user study*. Retrieved June 27, 2008 from http://ejust.stanford.edu/SR-786.ejustfinal.html

Kim, H.-C., & Eklundh, K. S. (2001). Reviewing practices in collaborative writing. *Computer Supported Cooperative Work, 10*(2), 247-259.

Kim, J. (2007). Motivating and impeding factors affecting faculty contribution to institutional repositories. *Journal of Digital Information, 8*(2). Retrieved on March 15, 2008 from http://journals.tdl.org/jodi/article/viewArticle/193/177

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

Kuhlthau, C. C. (1991). Inside the search process: Information seeking from the user's perspective. *Journal of the American Society for Information Science, 42*(5), 361-371.

Kuruppu, P. U., & Gruber, A. M. (2006). Understanding the information needs of academic scholars in agricultural and biological sciences. *Journal of Academic Librarianship, 32*(6), 609-623.

Lawal, I. (2002). Scholarly communication: The use and non-use of e-print archives for the dissemination of scientific information. *Issues in Science and Technology Librarianship*, *36*. Retrieved August 11, 2008 from http://www.istl.org/02-fall/article3.html

Leahey, E., Entwisle, B., & Einaudi, P. (2003). Diversity in everyday research practice: The case of data editing. *Sociological Methods & Research, 32*(1), 63-89.

Marshall, C. C. (1998). Toward an ecology of hypertext annotation. *Proceedings of the Ninth ACM Conference on Hypertext and Hypermedia: Links, Objects, Time and Space—Structure in Hypermedia Systems* (pp. 40-49). New York: ACM.

Marshall, C.C. (2005). Reading and interactivity in the digital library: Creating an experience that transcends paper. In D. Marcum & G. George (Eds.), *Digital Library Development: The View from Kanazawa* (pp. 127-145). Westport, Connecticut: Libraries Unlimited, 2005. Retrieved on November 12, 2008 from http://www.csdl.tamu.edu/~marshall/pubs.html.

Marshall, C. C., & Bernheim Brush, A. J. (2004). Exploring the relationship between personal and public annotations. *Proceedings of the 4th ACM/IEEE-CS Joint Conference on Digital Libraries* (pp. 349-357). New York: ACM.

McNicol, S. (2003). LIS: The interdisciplinary research landscape. *Journal of Librarianship and Information Science, 35*(1), 23-30.

Meho, L. I., & Tibbo, H. R. (2003). Modeling the information-seeking behavior of social scientists: Ellis's study revisited. *Journal of the American Society for Information Science and Technology, 54*(6), 570-587.

Mote, L. J. B. (1962). Reasons for the variations in the information needs of scientists. *Journal of Documentation, 18*(4), 169-175.

Murphy, J. (2003). Information-seeking habits of environmental scientists: A study of interdisciplinary scientists at the environmental protection agency in Research Triangle Park, North Carolina. *Issues in Science and Technology Librarianship, 38*. Retrieved May 30, 2008, from http://www.istl.org/03-summer/refereed.html

Nicholas, D., Huntington, P., & Jamali, H. R. (2007). The use, users, and role of abstracts in the digital scholarly environment. *The Journal of Academic Librarianship, 33*(4), 446-453.

Nicholas, D., Huntington, P., Jamali, H. R., & Watkinson, A. (2006). The information seeking behaviour of the users of digital scholarly journals. *Information Processing and Management, 42*(5), 1345-1365.

Nicholas, D., Huntington, P., Williams, P., & Dobrowolski, T. (2004). Re-appraising information seeking behaviour in a digital environment: Bouncers, checkers, returnees and the like. *Journal of Documentation, 60*(1), 24–43.

O'Connor, B. C. (1993). Browsing: A framework for seeking functional information. *Science Communication,15*(2), 211-232.

O'Hara, K. P., Taylor, A., Newman, W., & Sellen, A. J. (2002). Understanding the materiality of writing from multiple sources. *International Journal of Human-Computer Studies, 56*(3), 269-305.

Palmer, C. L. (1996). Introduction. Navigating among the Disciplines: The Library and Interdisciplinary Inquiry, *Library Trends, 45*(2), 129-133.

Palmer, C. L. (1999a). Aligning studies of information seeking and use with domain analysis. *Journal of the American Society for Information Science, 50*(12), 1139-1140.

Palmer, C. L. (1999b). Structures and strategies of interdisciplinary science. *Journal of the American Society for Information Science, 50*(3), 242-253.

Palmer, C. L. (2001a). The information connection in scholarly synthesis. In R. G. McInnis (Ed.), *Discourse synthesis: Studies in historical and contemporary social epistemology* (pp. 125-141). Westport, CT: Praeger.

Palmer, C. L. (2001b). *Work at the boundaries of science: Information and the interdisciplinary research process.* Dordrecht, The Netherlands: Kluwer.

Palmer, C. L. (2004). Thematic research collections. In S. Schreibman, R. Siemens, & J. Unsworth (Eds.), *Companion to Digital Humanities*, (pp. 348-365). Oxford: Blackwell, pp. 348-365. Available at http://www.digitalhumanities.org/companion/

Palmer, C. L. (2005). Scholarly work and the shaping of digital access. *Journal of the American Society for Information Science and Technology, 56*(11), 1140-1153.

Palmer, C. L. (2007). Adapting digital information to scientific practices. *International Association of Scientific, Technical & Medical Publishers STM Spring Conference: The Next Generation: Endless Choices & Economic Constraints. Cambridge, MA, 24-26 April 2007*. Retrieved September 10, 2008, from http://hdl.handle.net/2142/700

Palmer, C. L., & Cragin, M. H. (2008). Scholarly information work and disciplinary practices. *Annual Review of Information Science and Technology, 42*, 165-211.

Palmer, C. L., Cragin, M. H., & Hogan, T. P. (2004). Information at the intersections of discovery: Case studies in neuroscience. *Proceedings of the 67th American Society for Information Science and Technology Annual Meeting, 41*(1),448-455. November 2004, Providence, RI.

Palmer, C. L., Cragin, M. H., & Hogan, T. P. (2007). Weak information work in scientific discovery. *Information Processing and Management, 43*(3), 808-820.

Palmer, C. L., & Neumann, L. J. (2002). The information work of interdisciplinary humanities scholars: Exploration and translation. *The Library Quarterly, 72*(1), 85-117.

Palmer, C. L., Teffeau, L. C., & Newton, M. P. (2008). Identifying factors of success in CIC institutional repository development - final report. New York: The Andrew W. Mellon Foundation. Retrieved September 23, 2008 from http://hdl.handle.net/2142/8981

Park, J.-H., & Qin, J. (2007). Exploring the willingness of scholars to accept open access: A grounded theory approach. *Journal of Scholarly Publishing, 38*(2), 55-84.

Piwowar, H. A., Day, R. S., & Fridsma D. B. (2007). Sharing detailed research data is associated with increased citation rate. *PLoS ONE, 2*(3): e308. Retrieved September 12, 2008, from http://www.plosone.org/article/info:doi%2F10.1371%2Fjournal.pone.0000308

Reed, B., & Tanner, D. R. (2001). Information needs and library services for the fine arts faculty. *The Journal of Academic Librarianship, 27*(3), 229-233.

Research Information Network. (2006). *Researchers and discovery services: Behaviour, perceptions, and needs*. Retrieved October 15, 2008, from http://www.rin.ac.uk/researchersdiscoveryservices

Renear, A. H. (2006). Ontologies and STM publishing. *STM Innovations Seminar, London, UK, 1 December, 2006.*

Renear, A. H. (2007). Standard domain ontologies: The rate limiting step for the "Next Big Change" in scientific communication. *The 233rd American Chemical Society National Meeting, Chicago, IL, 25-29 March, 2007.*

Rheinberger, H.-J. (2003). "Discourses of circumstance": A note on the author in science. In Biagioli, M. & Galison, P. (Eds.), *Scientific authorship: Credit and intellectual property in science* (pp. 309-323). New York: Routledge.

Royal Society Scientific Information Conference (1948). *Report and papers submitted*. London: Royal Society.

Schatz, B., Mischo, W., Cole, T., Bishop, A., Harum, S., Johnson, E., et al. (1999). Federated search of scientific literature. *IEEE Computer, 32*(2): 51-59.

Schilit, B. N., Golovchinsky, G., & Price, M. N. (1998). Beyond paper: Supporting active reading with free form digital ink annotations. *CHI '98: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, (pp. 249-256). New York: ACM Press.

Siegfried, S., Bates, M. J., & Wilde, D. N. (1993). A profile of end-user searching behavior by humanities scholars: The Getty Online Searching Project Report No.2. *Journal of the American Society for Information Science, 44*(5), 273-291.

Sonnenwald, D. H., Maglaughlin, K. L., & Whitton, M. C. (2004). Designing to support situation awareness across distances: An example from a scientific collaboratory. *Information Processing & Management, 40*(6), 989-1011.

Soper, M. E. (1976). Characteristics and use of personal collections. *The Library Quarterly, 46*(4), 397- 415.

Spanner, D. (2001). Border crossings: Understanding the cultural and informational dilemmas of interdisciplinary scholars. *The Journal of Academic Librarianship, 27*(5), 352-360.

Sukovic S. (2008). Convergent flows: Humanities scholars and their interactions with electronic texts. *The Library Quarterly, 78* (3), 263-284.

Swan, A., & Brown, S. (2005). *Open access self-archiving: An author study*. Cornwall, UK: Key Perspectives. Retrieved on August 15, 2008 from http://www.keyperspectives.co.uk/openaccessarchive/reports.html

Talja, S., Keso, H., & Pietilainen, T. (1999). The production of `context' in information seeking research: a metatheoretical view. *Information Processing and Management, 35*(6), 751-763.

Tenopir, C. (2003). *Use and users of electronic library resources: An overview and analysis of recent research studies*. Washington, DC: Council on Library and Information Resources. Retrieved on May 15, 2008 from http://www.clir.org/pubs/abstract/pub120abst.html

Tenopir, C. (2006). How electronic journals are changing scholarly reading patterns. CONCERT Annual Meeting, Taipei, Taiwan, 2006. Retrieved September 10, 2008, from http://web.utk.edu/~tenopir/speeches/CONCERTtenopirPaperFinal.doc

Tenopir, C., King, D. W., Boyce, P., Grayson, M., & Paulson, K.-L. (2005). Relying on electronic journals: Reading patterns of astronomers. *Journal of the American Society for Information Science and Technology, 56*(8), 786-802.

Tenopir, C., King, D. W., Boyce, P., Grayson, M., Zhang, Y., & Ebuen, M. (2003). Patterns of journal use by scientists through three evolutionary phases. *D-Lib Magazine, 9*(5), Retrieved March 31, 2008, from http://www.dlib.org/dlib/may03/king/05king.html

Toms, E. G., & O'Brien, H. (2008). Understanding the information and communication technology needs of the e-humanist. *Journal of Documentation, 64*(1), 102-130.

University of Minnesota Libraries. (2006). *A multi-dimensional framework for academic support: A final report*. New York: Andrew W. Mellon Foundation. Retrieved May 28, 2008 from http://www.lib.umn.edu/about/mellon/UMN_Multidimensional_Framework_Final_Report.pdf

Unsworth, J. (2000). Scholarly primitives: What methods do humanities researchers have in common, and how might our tools reflect this? *Symposium on Humanities Computing: Formal Methods, Experimental Practice*, May 13, King's College, London. Retrieved March 26, 2008, from http://jefferson.village.virginia.edu/~jmu2m/Kings.5-00/primitives.html

Vakkari, P., & Talja, S. (2006). Searching for electronic journal articles to support academic tasks: A case study of the use of the Finnish National Electronic Library (FinELib). *Information Research, 12*(1), Retrieved March 28, 2008, from http://informationr.net/ir/12-1/paper285.html

Van House, N. A., Butler, M. H., & Schiff, L. R. (1998). Cooperative knowledge work and practices of trust: Sharing environmental planning data sets. *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work,* (pp. 335-343). New York: ACM Press.

Varghese, S. A., & Abraham, S. A. (2004). Book-length scholarly essays as a hybrid genre in science. *Written Communication, 21*(2), 201-231.

Vibert, N., Rouet, J.-F., Ros, C., Ramond, M., & Deshoullieres, B. (2007). The use of online electronic information resources in scientific research: The case of neuroscience. *Library & Information Science Research, 29*(4), 508-532.

Walsh, J. P., & Bayma, T. (1996a). Computer networks and scientific work. *Social Studies of Science, 26*(3), 661-703.

Walsh, J. P., & Bayma, T. (1996b). The virtual college: Computer-mediated communication and scientific work. *The Information Society, 12*(4), 343-363.

Walsh, J. P., Kucker, S., Maloney, N. G., & Gabbay, S. (2000). Connecting minds: Computer-mediated communication and scientific work. *Journal of the American Society for Information Science, 51*(14), 1295-1305.

Wang, P., & White, M. D. (1999). A cognitive model of document use during a research project. Study II. Decisions at the reading and citing stages. *Journal of the American Society for Information Science, 50*(2), 98-114.

Weisgerber, D. W. (1993). Interdisciplinary searching: Problems and suggested remedies. A report from the ICSTI Group on Interdisciplinary Searching. *Journal of Documentation, 49*(3), 231-254.

Westbrook, L. (2003). Information needs and experiences of scholars in women's studies: Problems and solutions. *College & Research Libraries, 64*(3), 192-209.

White, H. D. (1996). Literature retrieval for interdisciplinary syntheses. *Library Trends, 45*(2), 239-264.

Wiberley, S. E., Jr. (2003). A methodological approach to developing bibliometric models of types of humanities scholarship. *The Library Quarterly, 73*(2), 121-159.

Xia, J., & Sun, L. (2007). Factors to assess self-archiving in institutional repositories. *Serials Review, 33*(2), 73-80.

Zainab, A. N., Huzaimah, A. R., & Ang, T. F. (2007). Using journal use study feedback to improve accessibility. *The Electronic Library, 25*(5), 558-574.

Zhang, Y. (2001). Scholarly use of internet-based electronic resources. *Journal of the American Society for Information Science and Technology, 52*(8), 628-654.

Zimmerman, A. S. (2003). *Data sharing and secondary use of scientific data: Experience of ecologists*. Unpublished doctoral dissertation, University of Michigan, Ann Arbor.