Objectifying the Book: The Impact of Science on Books and Manuscripts

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Introduction

THE APRIL 1957 ISSUE OF *Library Trends* devoted to rare books contains no suggestion of the extraordinary impact science would have on the study and care of books in the years to follow.[1] Certainly this was not because significant efforts had not already taken place. Perhaps the authors underestimated the accomplishments and potential of science for this field. After all, not until six months after the issue's publication would Sputnik be orbited bringing in its wake a sudden wave of science-related publicity to the general population, heralding a period of great public interest in the sciences. Nine years later, the Arno river would sweep over Florence leaving the chief cultural treasures of the city near total ruin. The subsequent international rescue effort focused the attention of a public, by then attuned to science's potential, on both the enormity of the disaster and on the application of science to the preservation of cultural artifacts, including books. For some, as with the Sputnik launching, this sudden revelation of the benefits of science for material culture implied that these strides resulted from the event rather than from decades of patient experimentation. Of course such was not the case. Like flashbulbs in a darkened room, both events served to throw in sharp relief developments that had long been underway. While

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Sputnik and the Arno may have had some effects on scientific research, these influenced the intensity of such efforts far more than their direction.[2]

It is the purpose of this essay to outline the history of scientific investigations into the makeup and care of rare books and manuscripts.[3] The narrative is divided into three parts. It begins with the first stirrings in the eighteenth century and follows these down to the eve of World War II when systematic studies rapidly proliferated and were first integrated into the specific needs and questions posed by libraries with historical collections. Next is an overview of the increasingly quickened pace and deepening specialization of researches which have characterized the period from the eve of World War II to the present. This essay is then concluded by a summary of some of the less apparent effects of these developments with an eye toward how these have reshaped contemporary conceptions of the physical book.

This is a wide net to cast and the lines have been trimmed to narrow the discussion. First, science is taken in its more limited sense to refer to the systematic collection of information through physical analysis and experimentation.[4] Second, only those developments which reflect a direct engagement with books and manuscripts as physical objects (as opposed to their textual or iconographical content) have been included. Thus, for example, there will be no discussion of the computer's arrival in rare book repositories,[5] nor will any consideration be given to such other interesting and relatively long-lived efforts as those to secure or reformat books.[6] Last, restricted space has meant that the history of leather- and parchment-related developments and those connected with the effects and control of vermin will not be covered.[7]

Finally, a word on the title which underscores an underlying current of this essay. Whether for the purposes of interpretation or preservation, science has been both forming and revealing the basis for a clearer understanding of the book as a physical object. By opening a window into the opportunities science allows for preserving and probing the evidence imbedded in books, perhaps this essay can contribute to their more rigorous preservation as cultural artifacts and to widening investigations into the many layers of information they have yet to yield.

Beginnings

The earliest experimenters to apply scientific tools and methods to library materials were generally isolated from one another historically and geographically. One result of this separation was a loss of many important discoveries followed by subsequent efforts, years later, which would cover much the same ground. It was not until quickly proliferating researches internationally were linked by industrial applications and a growing public interest at the end of the nineteenth century, that the many developments in this area began to cohere into a distinct body of knowledge. Almost from the beginning two courses of inquiry could be distinguished: one centered on the durability of books and manuscripts stimulated initially by concerns over damaging storage conditions and the faulty manufacture of the materials of which library materials are composed; the other line of study applied increasingly refined techniques and instruments of the physical and natural sciences to the investigation of books and manuscripts, though almost exclusively for forensic purposes. Neither of these two avenues of study had an immediate or direct impact on the care or investigation of library materials in their day. Nonetheless, they provided the foundation upon which today's highly sophisticated approaches are built.

Englishman William Lewis (1708-1781), like many in his time, sought ways by which the practical necessities of life could be improved. Among the several concerns he addressed in his *Commercium Philosophico-Technicum* (1763) was the tendency of contemporary writing inks to fade. Not content to merely create new ink formulas and apply these in practice, Lewis attempted to assure that his recipes be able to withstand the test of time. He correctly observed the effects of sunlight in accelerating aging and applied this phenomenon in a series of experiments. For these he prepared swatches of paper inscribed with different ink formulas and then exposed them to sunlight. After several months of exposure he carefully evaluated the results.[8] Though not wholly conclusive, this investigation led to a related observation that faded writings in some manuscripts could be strengthened by brushing the leaves "with an infusion of galls."[9] It is not certain that Lewis was the first or even the only figure to note this reaction. Nonetheless, the practice of applying gall washes to manuscripts gained some acceptance in the eighteenth century, sometimes with near-disastrous consequences.[10] However, it was only after the beginning of the nineteenth century that experimental studies of library materials, especially paper, began to be subjected to more precise and verifiable tests. Among the earliest such analyses was one conducted by the prominent English physicist and chemist, Michael Faraday (1791-1867), while he was still a young and relatively unknown laboratory assistant in London's Royal Institution. At the behest of fellow Englishman and early experimenter in color relief printing, William Savage (1770-1843), Faraday analyzed a number of Savage's favorite printing papers—all foreign made—to gain insight into the reasons for their especially desirable qualities in order to prod

English papermakers into duplicating these. The test results, published as an appendix to Savage's *Practical Hints on Decorative Printing* (1822), were numerous and precise but revealed little useful information about the papers as Faraday himself remarked.[11]

It was during this period that concern began to be voiced over the declining quality of printing papers. Perhaps the earliest and undoubtedly the most acute critic of early nineteenth-century papers was English experimenter John Murray (1786?-1851). In a letter to *The Gentleman's Magazine* published in the July 1823 issue, Murray called attention to "the present state of that wretched compound called Paper," citing as an example his 1816 Bible which Murray described as "crumbling, literally, into dust." He concluded his missive with the results of a series of tests on paper from his Bible, extraordinary in their accuracy:

> To the tongue it presents a highly astringent and aluminous taste.
> On a heated metallic disc the leaf evolves a volatile acid, evincing white vapours with ammonia.
> The paper is brittle as tinder, and of a yellowish tint. The ink is brown.
> Litmus paper was reddened in a solution of the leaves in distilled water.
> Hydriodate of potassa became greenish yellow, from free sulphuric acid, or rather from the excess of that acid, obtaining in the supersulphate of alumina (allum).
> Osallate of ammonia gave the usual indications of lime.
> Nitrate of silver exhibited the presence of muriatic acid, no doubt resulting from the chlorine employed in whitening the rags or paper.
> Nitrate of baryta proved the presence of sulphuric acid, or of a sulphate.[12]

Murray expanded on these findings in subsequent publications,[13] but the range and accuracy of his 1823 tests would not be improved upon for more than sixty years.

The problems of which Murray complained had their origins in the almost frantic search by late eighteenth- and early nineteenth-century papermakers for larger and less expensive sources of raw materials to supply a growing popular appetite for printed matter. The by now familiar sequence of developments—including the introduction of alum-rosin size in 1807 and the expanding use of groundwood pulp in the 1840s followed by chemically rendered wood pulp shortly thereafter—led to a sharp decline in durability of nearly all printing and writing papers in subsequent years.[14] As more and more citizens such as John Murray began to decry the impermanence of contemporary papers, pressures mounted for the establishment of government standards of quality to assure the permanence of printed and written materials.

The Germans led the response by founding an imperial testing station in Charlottenburg (now part of Berlin) about 1885.[15] Though several German scientists had already been studying the subject before the testing station was established, [16] the Charlottenburg program accelerated the scientific investigation and quantification of paper's impermanence and means for correcting it. The outcome of the program's studies in Germany was generally limited to the creation of paper manufacturing standards for government documents. Not until 1898 did the Germans' pioneering efforts find a larger, international audience.

In response to growing public alarm in England over the deterioration of paper, the council of the Royal Society of Arts, founded in 1755 and devoted to the "Encouragement of Arts, Manufactures, and Commerce," appointed in 1897 a "Committee to investigate the causes of the deterioration of paper."[17] Among its members was Charles Frederick Cross (1855-1935), an expert on the nature and uses of cellulose, the basic building block of all papers. It was almost certainly Cross who brought to the committee and to the society knowledge of the experiments underway in Germany, as evidenced in his own published work.[18] The committee's report, first published in the *Journal of the Society of the Arts* (1898) and later as a book with appendixes (including abstracts of eighty-seven studies which emanated from Charlottenburg between 1885 and 1896), was designed to both explain the causes for paper's deterioration and to promote standards improving the quality of English-manufactured papers.[19] The report marked an important turning point in the preservation of library materials for two reasons: first, the committee bridged the gap between an increasingly specialized area of scientific inquiry and the cultural institutions whose collections would benefit from such research; second, the committee accepted and transmitted a body of scientific evidence as a means of both verifying its position and advocating its cause. The committee's lattermost role in consolidating, interpreting, and disseminating the work of the German scientists has remained its most influential accomplishment. Although little came of the committee's goal to raise the quality of English papermaking, the wider audience it created for the German researchers appears to have prompted a wide proliferation of similarly motivated studies throughout Europe and America that would continue to the eve of World War II.[20] The several hundred subsequent articles and monographs—though advancing investigatory methods and tools for enlarging knowledge of the causes of paper deterioration and proposing higher standards for paper manufacture and storage conditions—did not result in the discovery of effective paper restoration techniques for already deteriorated papers[21] or in a cost-effective technology for a truly permanent and durable paper by today's standards. Only when William J. Barrow inaugurated his own research program in 1935 would significant advances for the betterment of paper restoration and paper manufacture begin to take place.[22]

Throughout this early period strides were also made into the scientific investigation of books and manuscripts to answer historical and cultural questions as well. The versatile German scientist, Julius Wiesner (1838-1916), applied his skills to the doubts surrounding the makeup and origin of materials in the "Papyrus Erzherzog Rainer" in the Oesterreichishe Museum, Vienna in 1887, for example. Using microscopy and chemical analytics, Wiesner demonstrated that the fragments were actually early wove or laid papers, perhaps dating from the eighth or ninth centuries and thus among the earliest examples of papermaking in the West.[23] Such studies motivated by historical or cultural concerns were highly infrequent, however. This is not to claim that scientific investigations into library materials, especially manuscripts, were not underway. Toward the end of the nineteenth century, the evidence produced by these studies began to gain acceptance in American and English courts of law for adjudications hinging on questioned documents. A very active and highly-skilled community of professionals soon formed around the problems of analyzing questioned documents and presenting the results in ways acceptable in legal forums. A pioneer in this field was American Persifor Frazer (1844-1909) who first began publishing his techniques in the 1880s.[24] Frazer's most influential work, both among his peers and others, was *A Manual of the Study of Documents* (1894).[25] Beginning by coining the term "bibliotics" to describe his specialty, Frazer proceeded to explain it as:

> The study of all the materials used in making designs for the transmission of intelligence, as well as the individual character exhibited in the designs themselves; and though it is distinct from art conceptions, from literary or historical criticism of the intelligence conveyed, and from accurate chemical investigation into the nature of bodies, yet it accepts and needs the aid of all three of these studies in obtaining its results.[26]

Frazer followed with chapters on "Magnifying Instruments," "Colored Prisms" (for colorimetric analysis), "Quantitative Methods," and "Chemical Examination" to cite just a few. In 1901 Frazer revised and republished his work under the title *Bibliotics or the Study of Documents* deemphasizing a mastery of the "intricacies connected with getting conclusions in legal form before the courts" in order to give greater attention to "the means of applying scientific principles to the investigation of practical problems concerning documents."[27] Frazer's approach was adopted by several others including Albert S. Osborn

(1858-1946), who brought a number of innovations to the photography and visual examination of documents including the use of ultraviolet light[28] and Charles Ainsworth Mitchell (1867-?) who urged the use of techniques developed by the paper industry for microscopy and chemical analysis.[29]

Although the forensic scientists laid the groundwork for scientific investigations into manuscripts and books and the effective documentation of their findings, general knowledge of this work remained confined to legal circles.[30] The first to synthesize this body of research and, along with studies in other fields, apply it to historical questions raised by library materials was Reginald B. Haselden (1881-?), then curator of manuscripts at the Huntington Library. In the preface to his seminal *Scientific Aids for the Study of Manuscripts* (1935) Haselden remarks:

> In recent years scientific knowledge has extended its sphere of usefulness to almost all fields of endeavor. The question is whether this knowledge can be utilized and brought to bear on the complex problems encountered by the paleographer and the student of literary and historical manuscripts....
>
> The purpose of this book is to prove the value of scientific instruments in the solution of some of these problems, and to demonstrate the necessity of a scientific examination of the script as well as of the physical structure of the manuscript....
>
> Scientific instruments are helpful in three ways in the examination of manuscripts: first, in the solution of problems of interpretation relating to the text, physical history, and provenance; second, in the detection of forgery; and third, in the diagnosis of injuries and diseases.[31]

For the technical sections of his book which include chapters on "Light and Colour," "Illuminants and Light Filters," "Microscopes and Magnifiers," "The Ultra-violet Lamp and Flourescence," "Photography" (including infrared and "Röntgen-ray"), and "Measuring Instruments and Handwriting," Haselden draws heavily on the work of forensic scientists as well as that of specialists in the paper, ink, and photography industries. Haselden's highly systematic approach to the subject along with his nearly comprehensive and carefully cited bibliographies make *Scientific Aids* a major benchmark. However, Haselden limited his study to the first two of his categories of applications, scarcely touching on the "diagnosis of injuries and diseases."

Englishman Julius Grant (1901-?) agreed with Haselden's views but enlarged the latter's scope to include the problems of preventive care and restoration as well. Accordingly, Grant's *Books & Documents: Dating, Permanence and Preservation* (1937) is divided into two parts: the first, devoted to "The Dating of Books and Documents," includes chapters on "Dating Evidence from Paper," "Dating Evidence from Ink and Other Sources," and "Experimental Dating Tools"; the second part, focuses on "The Permanence and Preservation of Books and Documents" with chapters on "Paper Making [and 'Ink Manufacture'] from the Point of View of Permanence," "Tests for the Permanence of Paper and Ink," "The Influence of Light, Heat and Air on Permanence," "The Selection and Specification of Permanent Papers and Inks," and "Permanent Records: Methods of the Future" (including a section on microreformatting).[32] While Grant's book is not as thorough or, in some technical areas, as accurate as Haselden's, the breadth and integrative nature of its conception makes *Books & Documents* an equally important work. Grant's departure from Haselden's approach was no accident, for, as he noted in his preface:

> It is the author's hope that this work will have a threefold appeal—at least. Firstly, he trusts that it will prove helpful and interesting to librarians, collectors and antiquaries, and in fact to all those members of the general public who are sufficiently fond of books and documents to want to know something of their age, history and origin of the materials which comprise them, the extent to which these materials are likely to resist the ravages of time, and the best ways of assisting them to do so. Secondly, the book is addressed to scientific workers, amateur or professional, whether engaged in academic or industrial pursuits, whose work involves a study of these same matters as scientific problems; and thirdly to all those concerned with the manufacture and production of books or documents, namely papermakers, ink-manufacturers, printers, binders, publishers and of course authors.
>
> The writer feels that to provide something for every member of such a varied public is no mean task. If, however, he has succeeded in doing so... he will feel that the existence of this book has been justified because, so far as he is aware, no other work has yet appeared which has attempted to correlate these varied interests.[33]

By conceiving of a unified and mutually beneficial relationship between scientific studies of books for their care and those designed to answer historical questions, Grant heralded the arrival of the library-based laboratory where this approach to the physical book would be realized.

To the Present

The dimensions of William James Barrow's (1907-1967) contributions to the physical study and care of books and manuscripts have yet to be fully and accurately assessed.[34] First trained as a bookbinder, Barrow came to specialize in document restoration, establishing his own shop in 1932. He soon observed the relatively short life of conventional manuscript restoration techniques which included silking with a variety of materials as well as his preferred technique: cellulose acetate lamination. Barrow brought many improvements to the materials and presses necessary to this process,[35] but quickly realized that the problem of deteriorating papers and their repair—especially for the modern variety—required deeper investigation. By 1935 he had launched a personally-financed research program into the causes of deteriorating paper,[36] and by 1955 was prepared to publish his findings from a broad range of studies in *Manuscripts and Documents: Their Preservation and Restoration*.[37] Within its covers one can find literature reviews on the deterioration and restoration of writing and printing inks and papers, the effects of improper storage conditions, and most importantly, the results of Barrow's pioneering investigations into the chemical "deacidification" or more properly, alkalinization of papers for their preservation. The value of Barrow's efforts was broadly recognized, soon leading to a series of grants from the newly-formed Council on Library Resources, including a 1961 award to establish a library materials research and testing laboratory in space provided by the Virginia State Historical Society.[38] The breadth and character of Barrow's Council-sponsored researches were remarkable and the resulting publications continue to remain key references.[39] However, the significance of Barrow's accomplishments lie not with the particular innovations and discoveries which arose from his more than thirty years of experimentation but with the nature and rigor of his inquiries. Barrow transcended the symptoms of the problem to reverse their source. Furthermore, most of his research was conducted in the context of facilities designed specifically to investigate the materials with which he was concerned. Under his careful direction, the study and repair of library materials passed from reading room tables and bookbinders' benches to the counters of modern science laboratories with their attendant panoply of specialized methodologies and instrumentation.

Barrow's self-financed research lab of 1935 was followed by the creation of similar, though institution-based, facilities throughout Europe and North America. One of the earliest was Italy's Istituto di Patalogia del Libro in 1938.[40] This was followed by the founding of a succession of library materials conservation and research centers in Poland (1949),[41] the Soviet Union (1950),[42] Bulgaria (1956),[43] France (1963),[44] Spain (1969),[45] and the United States (1970).[46] Indicative of the growing number of scholars and conservation scientists active in these facilities and elsewhere, was the appearance of increasing numbers of articles devoted to books and manuscripts in such journals as *Studies in Conservation* (first published in 1952), *Art and Archaeology Technical*

Abstracts (which began publication in 1955), the *Journal of the American Institute for Conservation* (which began publication in 1960 as the *Bulletin of the American Group of the International Institute for Conservation*), and in 1969 *Restaurator, International Journal for the Preservation of Library and Archival Material* commenced publication. The frequency of specialized compilations began to grow during this period as well. Here studies on library materials appear as sections in larger books such as "Works of Art on Paper and Parchment" in *Conservation and Restoration of Pictorial Art* (1976),[47] or as the sections on paper-related materials in the Advances in Chemistry Series *Preservation of Paper and Textiles of Historic and Artistic Value* (volumes 1 and 2, 1977, 1981),[48] until, more recently, whole collections devoted to the field appear as with *Conservation of Library and Archive Materials and the Graphic Arts* (1985).[49] Specialized bibliographies also begin appearing, including Louise Louden's *Paper Conservation and Restoration* (1978)[50] and the Cunhas's *Library and Archives Conservation: 1980s and Beyond* (1983).[51] If one had to single out a handful of noteworthy research projects, certain efforts come immediately to mind including Reed's *Ancient Skins, Parchments and Leathers* (1972) in which he utilizes chromatography and electron microscopy studies to illustrate his points;[52] Roosen-Runge's *Farbgebung und Technik Fruhmittelalterlicher Buchmalerei* (1967) which, through a variety of sophisticated chemical analytics, documents a number of key pigments commonly employed by medieval illuminators;[53] Petushkova and Nikolaev's "Nuclear Magnetic Resonance Study of Parchment and Leather" (1983);[54] the cyclotron-based proton milliprobe studies of the Gutenberg Bible by Schwab, et alia (1983-1986);[55] and Humphrey's experiments with parylene conformal technology for preserving embrittled and otherwise unsalvageable books and manuscripts (1984-1986).[56]

The specialization of these researches and the publications which transmit them, coupled with their proliferation, readily daunt efforts to explain their direction or import. As this mass of data has grown and become increasingly dense it has also tended to obscure the great strides which have been taken in the care and historical investigation of books, particularly in the past half century. The tools necessary to explain and solve virtually all the conservation problems which can arise with library materials now exist. So too are the means for answering many scholarly questions where the clues lie buried in the object's physical composition. Indeed, a point has been reached where science has exceeded the ability of institutions or individuals to utilize it. Either the cost or the complexity of the technology to solve a particular problem is frequently perceived as overshadowing the value of the object in question, whether determined on a monetary or intellectual basis. For the curator confronted with day-to-day administrative responsibilities for thousands or millions of books and manuscripts, the existence of this body of knowledge and the facilities where it is being created or utilized in seemingly exotic investigations or restorations, appear as remote and perhaps inapplicable to the collection just down the hall. One could argue, returning to the 1957 issue of *Library Trends*, that even if the editor had considered covering the noteworthy developments in science and the physical book just then occurring, the article would have been out of place for a professional readership distracted by more immediate concerns. There may be some truth in this position though many would counter that a responsible custodian could find much information here directly applicable to the daily management of a rare book and manuscript collection. Nonetheless, and more to the point, an effect of the expanding number and frequency of researches over the past one hundred years has been a slow but inexorable shift in scholarly and curatorial perceptions of the book's infirmities and historical research potential.

Objectifying the Book

Scientific investigation in this century has based itself on the principle that a discovered or hypothesized truth can only be confirmed by methods and techniques which as much as possible are purely objective. Though a subjective observation may spark a thesis, the thesis can only be proved by means which do not include subjective observations as a trustworthy way of gathering evidence. The book's arrival in this arena of inquiry has implicitly necessitated an acceptance of certain limitations on the knowledge one can assume with regard to both the conservation and historical meaning of the physical book. For example, it is commonly known that while a book may appear as durable and more-or-less permanent, its chemical composition could limit its useful life to sixty or eighty years at most. The book's longevity cannot be accurately determined without a pH meter and other means of chemical analysis. Likewise one may suspect, based on a stylistic analysis, that two different illuminators contributed to the cycle of miniatures in a manuscript. Positive proof can only be achieved through a combination of microscopy and chemical comparisons of the pigments and paint application techniques.

These examples do not represent a complete suspension of judgment in one's approach to the materials in question. Rather they show how initial observations have become temporary stepping off points toward verification by other means, where once such observations would have been more likely to gain acceptance as conclusive in themselves. No longer are Berensonian-like pronouncements received as the last word in questions of a book's makeup. The authority of such statements is being displaced by a certain hesitancy born out of an awareness that imbedded within the book's structure lies information which, through science, can be revealed with much greater precision and reliability. Science has invaded the realm of curatorial judgment-making and connoisseurship.

The book has also been shown to be a very complex physical object. Its meaning has been enlarged by science which transcends the designs of bindings and illustrations and the patterns of knowledge expressed through texts to uncover much new information. Not surprisingly, science has drawn growing numbers of conservators and scholars alike to the portals it offers into the book. From these very specialized vantage points have emerged a host of techniques for providing better care for the book as well as fresh insights into many unanswered questions about its creation and transmission. However, the key to this opening into the physical book is an acceptance of the book as an object more completely understood through science, while at the same time accepting the objectivity of science as an appropriate method for posing and answering questions about the book. One must on occasion be willing to adopt the tools and techniques of science, necessitating both a different approach and different expectations. In other words, one must objectify the book to see it whole.

References

1. Peckham, Howard H., ed. "Rare Book Libraries and Collections." *Library Trends* 5(April 1957):417-94.

2. For a revealing glimpse of science in America almost a year before Sputnik, see: United States Congress. Joint Committee on Atomic Energy. Interim Report of the Subcommittee on Research and Development. *Shortage of Scientific and Engineering Manpower*, 84th Cong., 2d sess., 12 July 1956. A public policy overview of the American scientific community both in the years before and following Sputnik can be found in: Penick, James L., Jr., et al., eds. *The Politics of American Science: 1939 to Present*. Cambridge: MIT Press, 1972.

The Florence flood is frequently cited within the conservation profession literature as a major turning point in recent preservation history. This assumption is convincingly brought into question with regard to library materials in: Ogden, Sherelyn. "A Study of the Impact of the Florence Flood on the Development of Library Conservation in the United States: 1966-1976." M.L.S. thesis, University of Chicago, 1978. For a more readily obtainable though condensed version see: Ogden, Sherelyn. "The Impact of the Florence Flood on Library Conservation in the United States of America: A Study of the Literature Published 1956-1976." *Restaurator* 3(1979):1-36.

3. One could write at great length about what is meant by "rare book." Because the historical scope of this essay transcends the institutional sequestering and thereby *de facto* definition of the rare book, all scientific studies of printed codex-format materials have

been considered germane as well as those focusing on any manuscript forms whether in codex or more modern loose-leaf formats. Although not infrequently found in rare book collections, works of art on paper and photographic media have been deliberately excluded the restrict the length of this article.

4. Settling on a definition of science is no easy matter, particularly when the subject is viewed from the perspective of an institution such as the author's where the boundaries of disciplines are constantly brought into question and the conceptual foundations of science are themselves the subject of a degree-granting program. Nonetheless, a point of reference has been necessary and that provided by the *Oxford English Dictionary* has been a useful guidepost throughout: "A branch of study which is concerned with a connected body of demonstrated truths or with observed facts systematically classified and more or less colligated by being brought under general laws, and which includes trustworthy methods for discovery of new truths within its own domain. [And] often treated as synonymous with 'Natural and Physical Science,' and thus restricted to those branches of study that relate to the phenomena of the material universe and their laws...." *The Compact Edition of the Oxford English Dictionary.* Oxford: Oxford University Press, 1971, p. 2668.

5. The use of the computer in library environments remains generally limited to automated management of acquisition, cataloging, and circulation information which libraries possessed and administered before computers—albeit more slowly. The arrival of the computer has yet to change the nature of our knowledge about the book; it has only mechanized what we already knew. However, the applicability of the computer to the questions posed by the physical book may turn out to be, by definition, limited to the collection and analysis of data created through other means.

6. The author is aware that book and manuscript security is coming to be increasingly viewed as a function of library preservation administration. This organizational placement is based on an argument which characterizes security as a preventive aspect of an institution's efforts to maintain the physical integrity of its collections. While this position has its merits, it does not alter the fact that the tools and methods of library security are not directly applicable to the study or treatment of books and manuscripts.

Attempts toward creating photography-based facsimiles and micrographic reproductions of library materials can be traced to the dawn of photography itself in the mid-nineteenth century. For a concise, nearly exhaustively footnoted survey of the subject from Dancer's 1839 daguerrotype microcopy of a document to the 1950s development of xerography for the Atomic Energy Commission, see: Ballou, Hubbard W. "Photography and the Library." *Library Trends* 5(Oct. 1956):256-93.

7. There is a lamentable absence of leather conservation literature surveys, particularly with regard to the use of leather for bookbinding. For a very general and only partially applicable overview see: Stambolov, T. *Manufacture, Deterioration and Preservation of Leather: A Literature Survey of Theoretical Aspects and Ancient Techniques.* Amsterdam: Central Research Laboratory for Objects of Art and Science, 1969.

For a selective and accurate bibliography of the literature on library vermin and their control through the mid 1930s see: Weiss, Harry B., and Carruthers, Ralph H. *Insect Enemies of Books.* New York: New York Public Library, 1937. General sources containing subsequent studies will be given below.

8. Lewis, W. *Commercium Philosophico-Technicum.* London: For the Author, 1763, pp. 378ff.

9. Ibid., p. 380.

10. Instances of damage caused by gall washes and varnishes, colorless when first applied but which later turn dark yellow or brown, are not uncommon. For a recent testimony on the subject, see the "Editor's Note" for the facsimile: *Great Domesday.* London: Alecto Historical Editions, 1986 [unpaginated].

11. Savage, William. *Practical Hints on Decorative Printing.* London: Longman, Hurst, Rees, et al., 1822, pp. 80-85. Faraday says (p. 82): "I have been thus precise in describing the analyses, and the results afforded by them, rather to satisfy [Savage's] earnestness, than from an opinion that they present any thing capable of improving the art of paper making: and I should expect that matter much more interesting would arise

from an examination of the mechanical properties of the paper, and more applicable to the improvement of our own manufactory." It is unclear whether the particular tests employed by Faraday were specified by him or by Savage.

12. Murray, John [letter to editor]. *The Gentleman's Magazine* 93(July 1823):21-22.

13. ________. *Observations and Experiments on the Bad Composition of Modern Paper*. London: G. and W.B. Whittaker, 1824; and ________. *Practical Remarks on Modern Paper*. Edinburgh: William Blackwood, 1829. In the former, Murray recommends that printers test their papers for quality (p. 12), urging litmus (p. 17), and other tests (pp. 18-19) to achieve reliable results. In the latter, Murray's explanation of the deteriorative effects of alum which he accurately analyzed as bisulfate of alumina and thus an acid (pp. 81-82) and those of chlorine bleaches (pp. 82-83) were far ahead of his time.

14. There are a number of surveys on this subject ranging from the superficial to the excessively technical. One which strikes a fair balance is: Clapp, Verner W. "The Story of Permanent/Durable Bookpaper, 1115-1970." *Restaurator* (Supplement no. 3, 1972).

15. *Encyclopedia Britannica*, 11th ed., s.v. "paper."

16. One of the pioneers in Germany was Egbert von Hoyer (1836-1920). See for example: von Hoyer, Egbert. *Le Papier, Etude sur la Composition, Analyses et Essais*. Paris: Everling et Kaindler, 1884. An authorized French translation of Hoyer's book, it is printed seriatum on ten different types of paper with the beginning of each new sort labeled along the tail and fore-edges of the first recto with Hoyer's analytical categories, and the performance according to each, of the paper type in question. Hoyer's approach was based on physical characteristics and mechanical performance standards only. A comparison of the papers after one hundred years of natural aging with Hoyer's evaluations of their quality dramatizes the importance of understanding the chemical makeup of papers too if one is seeking to predict their permanence.

17. "Deterioration of Paper." *Journal of the [Royal] Society of Arts* 45(3 Sept. 1897):1055. This was not the Society's first expression of interest in the subject. See: Coleman, D.C. "Premiums for Paper: The Society and the Early Paper Industry." *Journal of the Royal Society of Arts* 107(April 1959):361-65.

18. Cross saw much of his work published. Two citations appropriate to this discussion are: Cross, C.F., et al. *Cellulose: An Outline of the Chemistry*. London: Longmans, Green and Company, 1895; and Cross, C.F. "The Industrial Uses of Cellulose." *Journal of the [Royal] Society of Arts* 45(18 June 1897):684-96.

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