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Kenneth O. May and information retrieval in mathematics

Albert C. Lewis

Indiana University–Purdue University Indianapolis, 425 University Boulevard, Indianapolis, IN 46202-5140, USA

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Abstract

From 1966 to 1977 Kenneth O. May led a team of University of Toronto staff and students that aimed to produce the most comprehensive general reference tools to date for the history of mathematics. The major published result was the 1973 *Bibliography and Research Manual of the History of Mathematics*, but also in the works was a dictionary and thesaurus of mathematical terms linked to their use in the literature. These works were intended to be a basis for subject indexing the whole of mathematical literature. His conceptual design and his goal and methodology, are useful examples in information retrieval.

Résumé

De 1966 à 1977 Kenneth O. May dirigea une équipe d'étudiants et de membres du personnel de l'université de Toronto dans le but de produire les outils de référence généraux les plus complets jusqu'ici pour l'histoire des mathématiques. L'ouvrage principal qui en résulta fut *Bibliography and Research Manual of the History of Mathematics*, paru en 1973, mais également prévu étaient un dictionnaire et thesaurus des termes mathématiques liés à leur utilisation dans la littérature. Ces travaux voulaient servir de base au classement des sujets de l'ensemble de la littérature mathématique. Le modèle conceptuel conçu par May, ainsi que son objectif et sa méthodologie, sont des exemples utiles dans la recherche documentaire.

MSC: 01A70; 01A60; 68A50

Keywords: Information retrieval; Kenneth O. May; Mathematics

1. Beginnings

Kenneth O. May founded *Historia Mathematica* in 1974 not only as a venue for publishing research in history of mathematics, but also as a tool for making research results in the field, wherever published,

E-mail address: alewis2@iupui.edu.

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accessible to both specialists and nonspecialists. The abstracts department was specifically directed at this goal, but this was only a part of May's ambitious information retrieval project. His ultimate goal was to build tools that would aid in the coverage of the literature of the whole of post-1800 mathematics. Literature in the history of mathematics was the key starting point in this venture since the discipline deals with the whole of mathematics through time and across cultures.

Tackling this project at that early stage of the "information age" in the 1970s involved a wide range of challenges. As will be discussed below, May had a certain skepticism toward adopting the latest computer technology in his work. Even if he did not anticipate the new media developed since his time, he can nevertheless be regarded as among the first to address old problems in ways useful for the new technologies: How does one keep up with the increasing quantity of literature? Is it possible to represent mathematical symbolism in a uniform fashion? What is the most efficient way for a user to search for information? Focusing on May's approach to these problems—his key design principles and how these principles have held up over the years since—we find valuable general lessons that are possibly uniquely expressed in his work. Most of the problems are well known to anyone who has constructed an index to a book, for example, but the following discussion assumes only that the reader has used indexes and not necessarily that he has studied the considerations behind them.

May appears not to have written any memoir or journal about his own work and its motivations. He started out in mathematical economics and social choice theory, where May's Theorem on Majority Rule remains one of the standard results. Given this background it is not too surprising that in the 1960s, when he made a transition from mathematics into the metamathematical fields of history and bibliography, the avenue was bibliometrics. His *Science* article [May, 1966] significantly refined a function published earlier by D.J. de Solla Price [Price, 1961], which measured the exponential growth in scientific literature. May's results were based on a tabulation of titles listed in the *Jahrbuch über die Fortschritte der Mathematik* from 1868 to 1940 and in *Mathematical Reviews* from 1941 to 1965. During this time he was also preparing his study "Growth and quality of the mathematical literature," published in *Isis* [May, 1968], in which he focused on the historical example of publications in the field of determinants. For this study he analyzed the rate of growth in terms of 1707 titles from the beginning of the 19th century up to 1920. He also classified these titles under six categories: new ideas and results; applications; systematization and history; texts and education; duplications; and trivia. Among his observations was his estimate that "all the significant information about determinants, including the main lines of the history of its ideas, is contained in less than 10% of the titles" [May, 1968, 367].

The year 1966 marked a turning point when May, at the age of 51, moved to Toronto and began devoting himself not just to further theoretical studies of the exponential growth of mathematical literature but to addressing the issue as a problem facing the mathematical community. In the face of such growth, how can the mathematician hope to find the literature that is most relevant to a given topic? At first sight, founding a journal and publishing yet more literature would not appear to be a step in the right direction, but May's contributions came with an antidote, so to speak: they provided aids for at least mitigating the problem by using abstracts, reviews, and indexes and the tools offered by bibliography and lexicography. In fact, in 1967 he signed a contract with McGraw–Hill to produce a dictionary of mathematics, of some 15,000 entries [Enros, 1980]. Though the dictionary never appeared, the proposal marked the new direction he was taking, and the card file which he started for it formed the basis of future work as will be discussed below.

A growing international network of historians of mathematics required means of communication and ways of mastering the growth and of evaluating the quality of the literature. It must not have been easy for

May to decide how to prioritize his efforts. The varied publications he produced addressed many of the most fundamental needs of this community: in addition to *Historia Mathematica*, he produced directories of mathematicians and historians of mathematics, argued for building up the archival record of modern mathematics, and pointed to the desirability of teachers knowing about the history of mathematics. A complete bibliography is provided in Enros [1984]; his main works related to information retrieval are:

- *The Mathematical Association of America*: *Its First Fifty Years* [May, 1972] was commissioned by the Association and edited by May. It is a compilation of essays by others relating to the Association's history. He credited Gregory H. Moore with compiling the extensive appendices that provide the fundamental information on such things as finances, membership, and officers.
- The *Bibliography and Research Manual of the History of Mathematics* [May, 1973] would be a worthy subject of a paper in itself. The graduate students who were employed on BRM, as it will be abbreviated here, included Charles V. Jones, Gregory H. Moore, Stephen Regoczei, and Henry S. Tropp. This work will come into the discussion again below.
- The abstracts department of *Historia Mathematica* was conceived as carrying on the comprehensive coverage begun by BRM. The abstracts department actually had a beginning in May's *Notae de Historia Mathematica*, the newsletter of the Commission on History of Mathematics, which first appeared in November 1971. It included "samples" of abstracts as part of its goal of preparing the way for the journal. It might be noted that the Commission was formed in 1969 and was the forerunner of the International Commission on the History of Mathematics.
- May was the translation editor for the *Encyclopedic Dictionary of Mathematics* [Iyanaga and Kawada, 1977]. It is not clear how deeply he was involved in this project.
- The *Index of the American Mathematical Monthly, Volumes 1 through 80 (1894–1973)* [May, 1977] provides substantial insight into May's overall objectives and will be a prime example here.

2. The issues

Perhaps the most intriguing information retrieval (IR) topic, if not the most important, is one that May worked on only, it seems, in connection with his 1968 *Isis* paper. There he discussed a bibliometric approach to qualitative analysis of the literature and for this he selected a subtopic of the pre-1920 literature on determinants, namely, the derivative of a determinant. In his conclusion he stated that we like to imagine that we are better off now than in this earlier period, that journals are more selective and referees more careful. "But," he added, "actually no one knows, and those with the widest familiarity are skeptical. Here again, there will probably be little improvement until historical and critical scholarship becomes an accepted part of mathematical work" [May, 1968, 371]. Evidently May's approach to qualitative comparisons shared the same requirement as bibliographies and indexes: a clear understanding of the way mathematical terms and symbols are used over time. His effort to meet this most basic need is the subject of what follows.

Most of the issues that May dealt with in his major projects are general IR issues. For example, it is desirable to uniquely identify people: Does "K.O. May" name the same person as "Kenneth O. May"? Keeping track of equivalence classes of names requires substantial work for any literature database of appreciable size; for *Mathematical Reviews*, for example, it is a major task. Another issue is search efficiency. Database theory devotes much attention to this but a common example arises in using a book index. How many "see" and "see also" references have to be gone through to get to the desired subject—assuming the subject is there? This issue of subject access ties in with vocabulary control, and it is evidently this topic and the issue of how to transcribe mathematical expressions that May decided were the first priority for any very useful comprehensive IR project.

Which subject terms should be used to enable subject access to the literature is a challenge even within a specialized subject like mathematics. Confining the language to just English in a specific time period, say, there are still many correct ways of describing the same thing. In addition, there is the question of how to incorporate notation so that mathematical expressions can be retrieved in the same fashion as text. This latter problem is unique to mathematics (though with similarities to the problem in chemistry of representing a molecular structure by a linear string of text) and has no general IR solution as yet. Looking at the issues of subject access and notation against the background of the development of computers and the new media since May's work, it appears that in general the rate of increase of computer use since May's time has not been matched by progress in addressing these issues.

3. Lessons from May's major projects

The *Bibliography and Research Manual* (BRM) remains a monumental work today. The IR lessons May learned through his own experience are shared in the section of the volume entitled "Personal Information Storage":

> Where a personal information system is very large and subject to frequent manipulation, it may be advisable to *consider* automation, and especially the use of computer filing, manipulation and storage. However, before information can be fed into a computer it must somehow be recorded and coded, so slips or equivalents must be made anyway. For most personal files, computerization is inconvenient and expensive. [May, 1973, 18]

In 1973 this was probably sound advice. Computers were considered but not used in the BRM project. Today a project designer would probably not think twice about doing the initial keyboarding directly into a computerized database. As textbooks in database theory try to make clear, however, the relative ease with which one can just begin "inputting" can lead to such hasty and poor initial planning of the database that the result is less useful and more expensive in the long run than envisaged.

May realized that it was a major limitation in BRM that there were no indexes; the only access is through the classification scheme under whose categories all of the entries are arranged. This sort of arrangement may suit browsing but becomes less friendly for a user who is trying to focus on a particular topic. Short of scanning nearly 600 pages, the reader can never be sure of looking under all relevant headings—biographical, time periods, mathematical topics, epimathematical topics, and historical classifications—let alone all the relevant subheadings under these. The key to solving this is a unified subject index and while May was working on BRM he was also making a substantial foray into just this area.

In his 1972 history of the Mathematical Association of America May referred to a forthcoming 80-year index to its journal, *The American Mathematical Monthly*, as an aid for further research into the history of the Association. He signed a contract for the index in 1971. When it appeared six years later May outlined in his preface the frustrations involved, which made it take longer to produce than expected. He was undertaking what he described as the first journal index on such a large scale. One of the features which sets it apart even today from many journal indexes is its provision of a subject index in addition to an author index. Progress on the ambitious project was slow. It proved difficult to make realistic projections of the time and money required, and this, together with the general economic situation of the Association in the mid-1970s, led the organization to withdraw their support for the whole index project after several years. However, after May came up with more economical plans for finishing it using the University of Toronto's mainframe text-editing system to produce camera-ready copy, the Association restored funding. In his preface he described how the index managed to be produced through these difficulties and then he described what the plan ought to have been in hindsight. The key difference was that instead of using card files as an intermediary medium, all data should have been entered directly into the computer—a change from his opinion in BRM just 4 years earlier. However, helpful this would have been to the overall timeline, this nevertheless would not, in May's estimation, have speeded up the labor-intensive stage of vocabulary control in the subject index.

To take an example from the index: in order to have useful entries under the notion of "inverse" and "inversion" there are 11 main entries, from "inverse circular functions" to "inversive geometry," with subentries and cross references under most of these. The indexer needs to find a balance between, on the one hand, simply picking terms directly from the indexed articles (essentially equivalent to automatic generation with some human prefiltering) and, on the other, developing a consistent, but possibly too narrow, master list of terms from which the terms for an article will be chosen when the latter uses variants or does not explicitly use the terms at all.

An example of cross references occurs: "inverse matrix" see "matrix inversion." In a typical printed index, cross references are designed to balance search efficiency with saving space. If there are a substantial number of citations under a term (typically locations identified by page numbers) then it is probably a more efficient use of space to put them under one "best" entry. How to decide which that main entry should be? May tried to identify the "most likely" term that a mathematical user would use to look up the concept. If space is not an issue then from the search efficiency point of view all the locations could be repeated under each entry. This might not be desirable, however, if one term is "nonstandard" in which case the indexer may wish to be proscriptive and guide the user to the preferred usage.

Vocabulary control in this broad sense motivated May to undertake work on a mathematical thesaurus in addition to his dictionary. "I hope in the not too distant future," he wrote in the preface to his 1977 index, "to publish a thesaurus and a dictionary on which I have been working for many years" [May, 1977, v–vi]. This dual project appears to have aimed ultimately at nothing less than providing a basis for indexing the whole of the mathematical literature. Unfortunately, 1977 was the last year of May's life. We can now only see the outline of what would have been the cornerstone for his grand task of providing in-depth subject access to the mathematical literature.

Shortly afterward Philip Enros, who had been a student of May, prepared a report on the status of the thesaurus and dictionary files for the May Committee of the Institute for the History and Philosophy of Science and Technology at the University of Toronto. It was his judgment that, though much work remained to be done on the dictionary, the thesaurus files were "largely complete." His report included copies of sample dictionary pages that May prepared for a grant application. One of the notable features was inclusion of references to the literature: first occurrences or fuller historical accounts, for example. The following details concerning the thesaurus come from Enros's report [Enros, 1980].

Most of the work on the thesaurus was done on slips of paper but at one point May ventured to put some material into a mainframe computer. Enros was able to access his account and found an arrangement of terms that began:

Abacus
  BT calculating instruments
  NT Chinese abacus
  NT sand table
Abbe-Helmert criterion
  BT randomness tests
Abbreviated sequences
  BT sequences of numbers
Abbreviations
  RT mnemonics
Abbreviation of fractions
  BT fractions
Abel addition theorem
  BT Abelian integrals
  BT addition theorems for integrals
  NT addition theorems for elliptic integral
  NT addition theorems for circular function
Abel combinatorial identities
  BT combinatorial identities
Abel continuity theorem
Abel convergence theorem

The abbreviations come from May's system of relations:

CT	complementary term,
IS	similar formal structure,
NT	narrower term,
BT	broader term,
UF	used for,
USE	use,
RT	related term,
OT	overlapping term.

This structure was to be backed up by the literature excerpts maintained for the dictionary, which came to some 73,000 five-by-eight slips containing about 36,000 terms. For the thesaurus May had prepared 9,100 three-by-five cards bearing the terms and relations. He would have made use of the subject classification scheme used in *Mathematical Reviews* and drawn from other sources as well. Altogether this mathematical thesaurus would evidently have been appreciably more elaborate than anything available today.[1]

[1] The thesaurus files are now a part of the Kenneth O. May papers at the archives of the University of Toronto. The dictionary files were not taken by the university archives and, in spite of efforts to find a home for them, sometime after Enros left Toronto they appear to have been misplaced. In 1996, in connection with the American Mathematical Society bibliographical project

The 80-year index to the *American Mathematical Monthly* gives us a small-scale model of the sort of subject index May had in mind. Even if it did not fully benefit from the developing thesaurus, it illustrates the value of such subject access to the literature and the challenges involved in enabling such access. Today digital facsimiles of all of the first 80 volumes and more can be found on the Web, where they are available with full-text searching. (Where, as will be discussed next, "full-text" does not necessarily mean that all the content is searchable.) The repository JSTOR, through its digitizing of complete runs of journals, is one of the positive developments in recent years toward utilizing the potential that computers have in aiding our access to the literature. However, it is precisely successes such as this that may mislead some users into downplaying the role of indexes such as May's. It is easy to demonstrate nevertheless the radical advantage of a good index in subject retrieval: look up in JSTOR some of the terms occurring in the entries centering on "inverse" mentioned earlier and compare the search results with those in May's index. Of course, the skilled, labor-intensive effort that goes into making such an index is, as May confirmed, expensive. Scanning and keyboarding text and bibliographic information for documents are straightforward tasks compared with reading and understanding the documents sufficiently to assign subject terms. Eventually computers may help to overcome this obstacle either by generating, in effect, a specialized thesaurus directly from the literature or by making use of a human-constructed thesaurus in automatically generating indexes. In any case, the pioneering work of May has helped to set the goal and show how to get there.

The *Monthly* index also raised for May the interesting issue of how to represent mathematical expressions if they are not to be ignored altogether. The JSTOR solution is to provide facsimiles of the printed pages. Thus, though it has no capability of searching for mathematical expressions, JSTOR can faithfully reproduce, for example, a title as it appears on the first page of the published article: "A New Method for the Evaluation of $\iint_A f(x, y)\,dy\,dx$." In picturing what May did with this title it should be kept in mind that he was using a combination computer terminal and printer consisting of an IBM Selectric typewriter connected to a remote server and it was this typewriter output that would be used for camera-ready copy. One of the usual selling points for this electric typewriter was that different fonts were available as type on separate hollow metal spheres, one for each font. However, font changes, such as switching to italics or to mathematical symbols, could only be accomplished manually by interchanging these font balls, and this was a feature May understandably wished to avoid. He considered an ambitious plan for "linearizing" mathematical notation, not only so that it could be typed using one standard font but also so that expressions could be alphabetized and indexed. This was not attempted in the end and the few expressions occurring in the tables of content were transcribed as they might be spoken; thus in the example title the expression appears as "`the double integral over A of f(x,y)dydx`." The JSTOR *Monthly* tables of contents utilize TeX and thus our title appears there as "A New Method for the Evaluation of `$\int\int_Af(x,y)dydx$`."

The typesetting program TeX was just being developed at about the time May's index was published in 1977. Though it probably would have satisfied May's requirements for "linearization," TeX does not come with a transcription standard; the same mathematical expression can be correctly encoded in different ways. For the double integral expression, for example, one TeX handbook suggests that it might be considered desirable to add a couple of "negative thin spaces" to bring the signs closer together than the default and to add thin spaces around the dy and dx, making the transcription

described below, enquiries were made of people who were at Toronto in the early 1980s and who seemed most likely to know, but the whereabouts of the files remains a mystery.

`$\int\!\!\!\int_Af(x, y)\,dy\,dx$`. Since May was not concerned with the finer points of typesetting, in principle he could have adapted TeX to his purposes, if it were available, even though TeX was not intended as a transcription standard.

The more recent MathML (Mathematical Markup Language, a part of XML) may stand a better chance of being used in the way envisaged for May's index. MathML, like any general markup system, allows the transcriber to concentrate on structure separately from appearance. (MathML makes a distinction between markup for content and markup for display and allows a mixture of the two.) Here is a representation of only the "double integral over *A*" part of the expression in MathML:

```
<mo>&int;</mo> <msub> <mo>&int;</mo> <mi>A</mi> </msub>
```

Here the containing element, `<mo>`, identifies its content as an operator, for example. Inputting these cumbersome-looking expressions can be aided by special editing software. MathML output can be rendered into original *Monthly* form by a suitably equipped Web browser or other reader.[2] As a general transcription method MathML has the advantage over May's method in that it uses a specialized language that can be read by a computer and has the advantage over TeX of leaving typesetting or rendering issues entirely up to another processing level and perhaps also allowing for less encoding creativity. There could well be other candidates for a transcription standard but there seems to be nothing in general use at present that would have satisfied all of May's ideal requirements. Certainly we are far from being able to "alphabetize" mathematical expressions and search for them in the way we can for ordinary text.

4. May's bibliographical legacy

BRM is still available today on a print-on-demand basis, though, at $200 US plus shipping for a paperback version, it is priced at the upper limits of the trade and may not be as accessible to all potential users as it once was.[3] Fortunately, the abstracts department of *Historia Mathematica*, which May envisioned as the continuation of BRM, has thrived. It was patterned somewhat after the Telegraphic Reviews that May initiated in the *Monthly*. (The 10-year subject index to the abstracts in the first issue of Volume 14 was modeled after May's *Monthly* index.) Both BRM and the *Historia* abstracts caught the attention of Keith Dennis when he became executive editor of *Mathematical Reviews* in 1995 and the American Mathematical Society (AMS) began to look for ways of augmenting the *Reviews* database that was available through the Web interface MathSciNet. Their idea was to convert into electronic form earlier indexes and bibliographies that previously existed only in print. Candidates that were in the public domain or otherwise free of charge were preferred, since the necessarily high conversion expense was unlikely to be recovered through sales. This condition excluded BRM, but from this exploration closer linkages developed between *Mathematical Reviews* and *Historia*. A quick and informal comparative study of their respective coverages of history showed that there was a substantial number of items that were in only one or the other of the two and that those items were about evenly divided between the two; i.e., one was not clearly outdistancing the other. *Mathematical Reviews* tended to include more biographical articles about living and recent mathematicians while *Historia* covered more articles from journals specializing in history of science.

[2] Information on MathML can be found on the Web through http://www.w3.org/.
[3] It can be obtained through the Web site http://wwwlib.umi.com/bod/.

It seems in retrospect to have been a natural move from the AMS's interest in May's bibliographies to their interest in a new edition of Joseph W. Dauben's *The History of Mathematics from Antiquity to the Present*: *A Selective Annotated Bibliography*, originally published in 1985. Dauben and the sponsor, the International Commission on the History of Mathematics, invited the author to take over the general editorship of this prominent bibliography and to oversee a revised and updated edition. The AMS proposed an electronic version on CD, encoded in TeX, and offered at a lower price than the original print edition [Lewis, 2000]. This bibliography was inspired by the same general spirit as May's comprehensive projects, but tried to act as a guide by selecting and commenting upon those works that would be suitable for a newcomer as starting points in each topic. One thing was quickly learned by the editors: it is much less troublesome for a bibliographer to simply gather and classify everything than it is to also evaluate, select, and annotate—tasks that could not have been accomplished for the bibliography without the participation of the many specialists who were contributing editors. It remains to be seen to what extent the electronic format enhances the dissemination and usefulness of the work.

During May's life the capability of making large quantities of entire documents available in electronic form was not widely regarded as a practical possibility for the foreseeable future. In any case, for May his Selectric terminal represented about the apex of his computer experience. His last work to be published was an address given in 1976 to computer scientists about the historiography of their field and in it he described his experience:

> For a long time I felt sure that the hand methods I was using were better and faster. Of course, if I had had unlimited funds, that would have been a different matter. I would occasionally check with people in our computer center, show them how I did things, and ask whether I could do it a little faster with computers. The answer was, "You'd better stick to your old-fashioned methods." [May, 1980, 12]

May gives indications in his talk that he may have been beginning to embrace computers more fully. We can only guess what this might have meant for the future direction of his IR work but up to this point he had at least been free to address fundamental issues that were independent of particular computer technologies.

To return to the larger picture of accessing the literature, big projects are in the making. The goal implied by the efforts of the AMS and others to convert literature to electronic form is nothing less than eventually digitizing and disseminating the whole of past mathematical literature. John Ewing, executive director of the AMS, has presented an overview of the state of affairs in which he summarized the task and the issues involved:

> The entire mathematical literature consists of approximately 50 million pages contained in books, journals, and various other publications. There are many ways to digitize the past literature... but the only cost effective way is to combine scanning with partial optical character recognition, creating a combination of scanned page image and associated text file (for searching). There is more to the process of course. Relevant bibliographic data about each item must be captured ...; proofreading of critical data has to be carried out. ...
>
> At the moment many projects are under way to digitize past scholarly literature. ... All this coincides with the explosion of recent mathematical literature that has gone online in a great variety of digital forms (and which will become past literature in the near future). Many different groups, with many different formats, with many different interfaces. Almost everyone has the same goal—to make the mathematical literature accessible to mathematicians—but without coordination and standards the effort will founder. Creating a basic set of standards for digital mathematical literature is essential in order to keep all these efforts from merely producing a Tower of Babel. [Ewing, 2002, 772]

Ewing's paper is concerned primarily with the key first step, standards for production and dissemination of the raw material—"bibliographic data, scanned images, associated text files, and other digital material"—and only mentions subject access as an important future concern. Historians are particularly sensitive to the fact that over the lifespan of a journal mathematical usage, meaning, and spelling of terms can change just as, for example, the English language itself changes. This fact is reflected in the changes that occur from time to time in subject classification schemes, such as that used by the AMS. In his dictionary and especially in his thesaurus May envisioned rather elaborate, history-based tools that could be a basis for accessing all of the past literature, not just the most recent. His remark from 1971 still stands: "Sooner or later the necessity for such a thesaurus will be realized" [Enros, 1980, 8].

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References

Enros, P.C., 1980. May Dictionary and Thesaurus Projects, Scope and Status Report. Institute for the History and Philosophy of Science and Technology, University of Toronto, Toronto.

Enros, P.C., 1984. Kenneth O. May—Bibliography. Historia Math. 11, 380–393.

Ewing, J., 2002. Twenty centuries of mathematics: digitizing and disseminating the past mathematical literature. Notices Amer. Math. Soc. 49, 771–777.

Iyanaga, S., Kawada, Y. (Eds.), 1977. Encyclopedic Dictionary of Mathematics. MIT Press, Cambridge, MA.

Lewis, A.C. (Ed.), 2000. The History of Mathematics from Antiquity to the Present: A Selective Bibliography, Edited by Joseph W. Dauben. American Mathematical Society, Providence, RI. Revised edition on CD-ROM.

May, K.O., 1966. Quantitative growth of the mathematical literature. Science (N.S.) 154, 1672–1673.

May, K.O., 1968. Growth and quality of the mathematical literature. Isis 59, 363–371.

May, K.O., 1972. The Mathematical Association of America: Its First Fifty Years. Mathematical Association of America, Washington, DC.

May, K.O., 1973. Bibliography and Research Manual of the History of Mathematics. Univ. of Toronto Press, Toronto.

May, K.O., 1977. Index of the American Mathematical Monthly, Volumes 1 through 80 (1894–1973). Mathematical Association of America, Washington, DC.

May, K.O., 1980. Historiography: a perspective for computing scientists. In: Metropolis, N., Howlett, J., Rota, G.-C. (Eds.), A History of Computing in the Twentieth Century. Academic Press, New York, pp. 11–18.

Price, D.J., de Solla, 1961. Science Since Babylon. Yale Univ. Press, New Haven, CT.