AMERICAN MATHEMATICAL SOCIETY

The History of Mathematics from Antiquity to the Present: A Selective Annotated Bibliography, Edited by Joseph W. Dauben

Revised Edition on CD-ROM
Albert C. Lewis, Editor, in cooperation with the International Commission on the History of Mathematics

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HOW TO GET STARTED

DESCRIPTION OF CD CONTENTS

The CD contains the text of The History of Mathematics from Antiquity to the Present: A Selective Annotated Bibliography, edited by Joseph W. Dauben: Revised Edition on CD-ROM, Albert C. Lewis, Editor. The CD is published by the American Mathematical Society in cooperation with the International Commission on the History of Mathematics.

The original work, The History of Mathematics from Antiquity to the Present: A Selective Annotated Bibliography, edited by Joseph W. Dauben, was published in 1985 and covered the literature up to 1982. This edition on CD-ROM covers the literature up to the present and has twice as many as the first.

The CD contains full bibliographic information for 4,800 entries and covers the history of mathematics beginning with the ancient civilizations. The various branches of mathematics and their applications to other fields are also covered. Annotations and introductory notes provide evaluation and context.

In addition, The CD contains Adobe™ Acrobat® Reader 4.0 with Search for Macintosh®, Windows®, or UNIX®; this help file; a table of contents; the front matter which includes copyright information and introductions; an author index; and a subject index.

HOW TO VIEW CONTENTS

For full functionality, you must have Adobe Acrobat Reader 4.0 with Search software installed on your computer. The software is included on the CD and should replace older versions of Acrobat Reader with Search or Acrobat Reader without Search.

You can browse through the text using the bookmark area; search the text using Acrobat Search; or link from an item in an index to the text of the entry.

LINKS TO TEXT

There are links from one point in the text to another.

The links to text within the CD are:

- From an index item to its text entry
- From text to a footnote
- From a bookmark to the corresponding area in the text
- From a search result to the corresponding area in the text

Note: Cross-references from one entry to another are not linked.

LINKS TO WEB SITES

When the URL for a Web site is given, the link is live if we were able to resolve the URL at the time of publication. If not, the URL is listed but not a link.

- Live links are in green.
- URLs at the end of a line may continue on the next line; click either section to link to the Web site.
- A browser is required to link to Web sites.
- Some browsers start automatically when a URL is selected; others must be opened first.

DISCLAIMER

URLs on this CD-ROM were viable at the time of CD-ROM publication; the American Mathematical Society does not guarantee their reliability in the future. URLs that could not be resolved at the time of CD-ROM publication are printed but are not live.

How to Install Adobe™ Acrobat® Reader 4.0 with Search

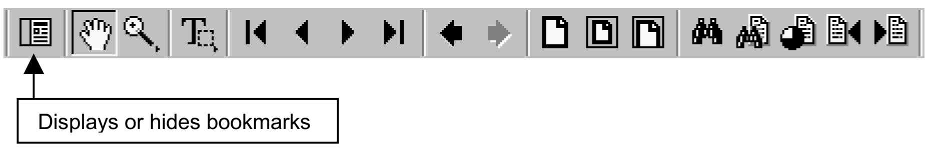
- Open the CD folder or directory
- Open the folder for your platform: Macintosh®, Windows®, or UNIX®
    - Macintosh and Windows - open the folder English-ENU then click on installer icon
    - Unix - open the folder of your operating system and then the tar file.

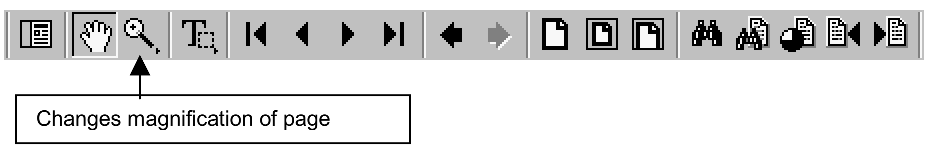
Follow the install instructions. If you have questions when installing Adobe Acrobat Reader, contact Adobe technical support at www.adobe.com.

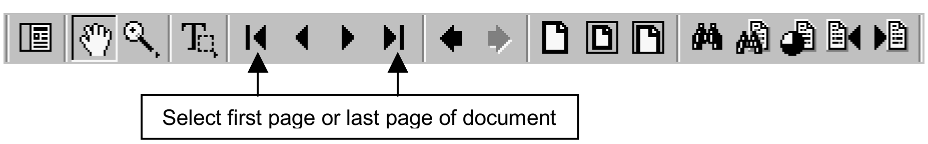
How to Use Adobe Acrobat Reader 4.0 with Search

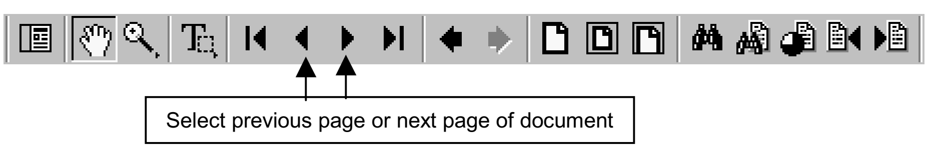
The CD relies on Adobe Acrobat Reader functionality. To get the most from the CD, become familiar with Adobe Acrobat Reader features, icons, and commands. Consult the Reader Guide available from Help in the Acrobat Reader toolbar for complete information.

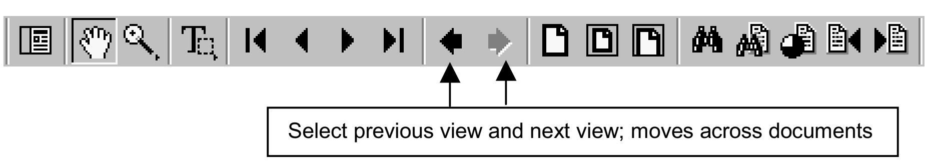
Useful Icons

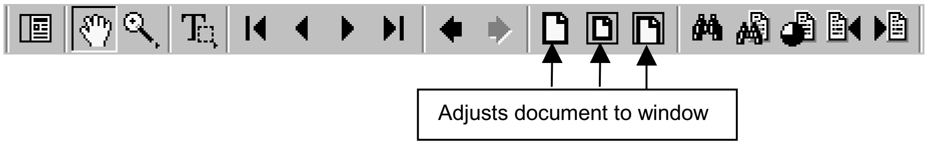


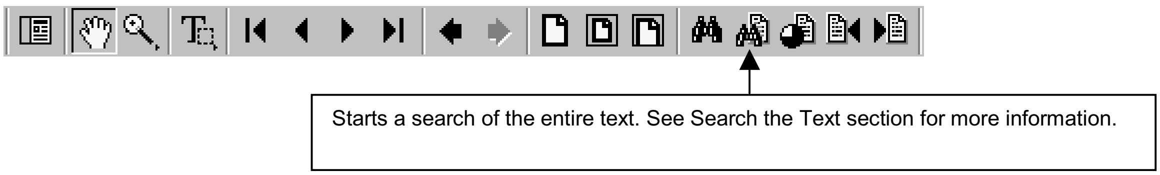












BROWSE USING BOOKMARKS

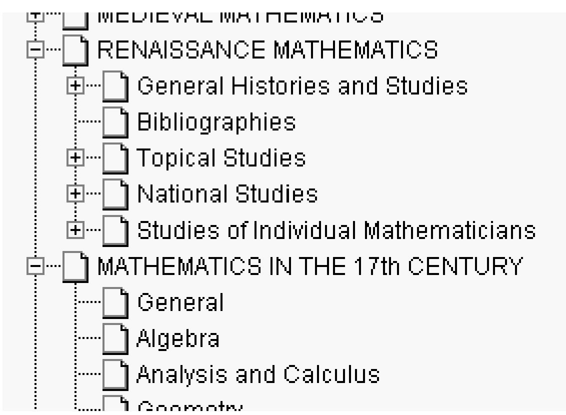
The table of contents is set up as bookmarks providing direct links to each chapter and section.

- The bookmarks are displayed to the left of the text.
- Click the Bookmark icon to toggle between showing or hiding the bookmark window.
- Headings may be expanded to view subheadings or collapsed for easier reading.
- Adjust the width of the bookmarks by clicking on the right-hand divider and moving it right or left.
- Bookmarks stay expanded when moving through a single file. At the end of a file, continue by clicking on a new section from the Bookmarks.
- Bookmarks collapse automatically when a link brings you to a new file.

NAVIGATING BOOKMARKS

The text of the CD is separated into files. In Example 1 below, RENAISSANCE MATHEMATICS and MATHEMATICS IN THE 17TH CENTURY are separate files. The subheadings under RENAISSANCE MATHEMATICS and MATHEMATICS IN THE 17TH CENTURY are included within their respective files. When you get to the end of a file, you will need to click on the next bookmark to continue.

Example 1 - Bookmarks



For help using bookmarks, click on Help in the Acrobat Reader toolbar and select Reader Guide.

LINK FROM AUTHOR OR SUBJECT INDEX

The CD has an author index and a subject index. Index entries are not consolidated and names may be listed several times.

Both indices are listed at the beginning and end of the bookmarks for easy access. In the bookmark window, click on Author Index or Subject Index. When the index is in the right-hand window, click on an item number or page number to go directly to the corresponding entry in the text. The full-hand icon will become a pointing-finger icon when over a link.

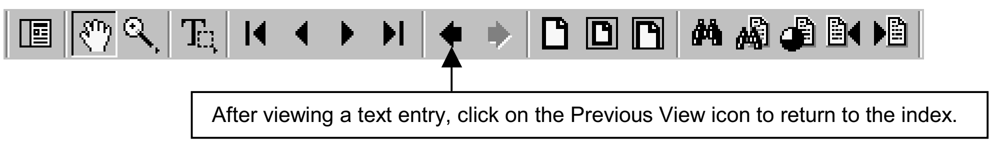
Example 2 - Index

Clicking on one of the entry numbers, for example 2590, would take you the entry of a work authored by Michael Bernkopf.

Bernes, Anne-Catherine, 2207
Bernkopf, Michael, 2590, 2591
Bernoulli, Daniel, 160

Return to Index from Entry

After viewing the text of an entry, you can return to the index by clicking the Previous View arrow indicated below. If you have paged ahead or back, you may have to click several times.



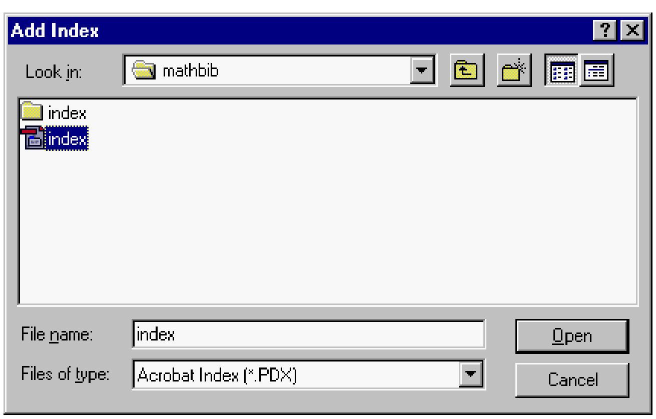
SEARCH THE TEXT

- The text of the CD must be searched using Adobe Acrobat Reader 4.0 with Search.
- The full text of the CD contents is searched.
- This is not a fielded database.
- The results are ranked by relevance.
- Searching on language-specific letters or diacritics (accents) or diphthongs is not possible.

For specific Search help, consult the Reader Guide available from Help in the Acrobat Reader toolbar.

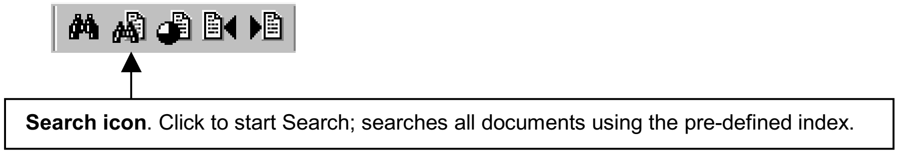
LOADING THE SEARCH INDEX

When you open the CD via Start_CD, the index loads automatically. If you open a different PDF file on the CD, the search index will not load and searching is not possible. To load the index, select the Search icon; from the search window, select Indexes; from the Index Selection screen, select Add. Then click on the icon labeled Index in the folder mathbib.



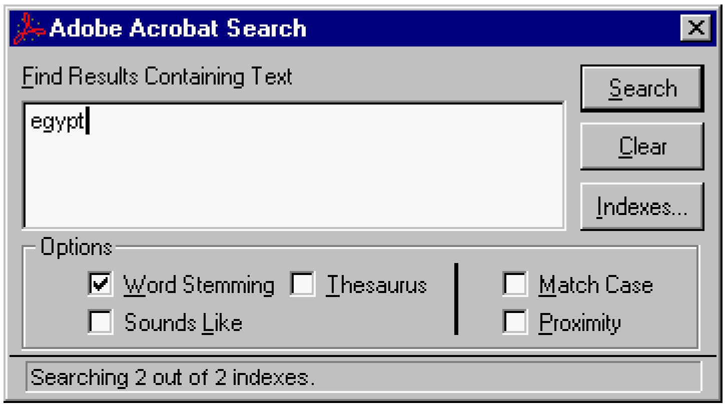
START A SEARCH

Start a search from **Edit > Search > Query** or by clicking on the Search icon.



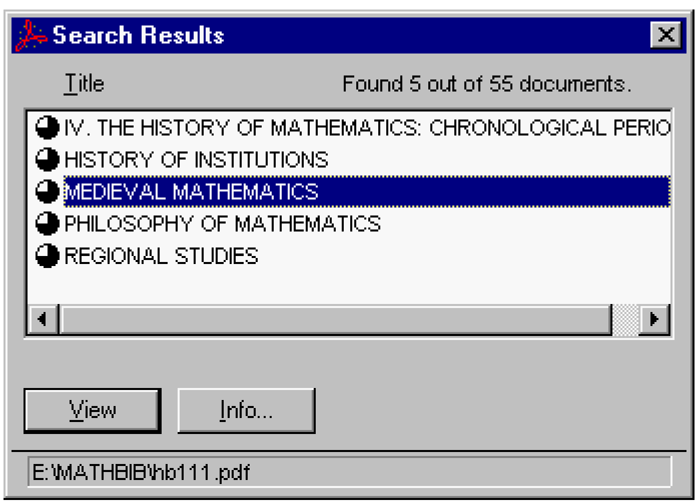
SEARCH SCREEN

Enter search criteria in the text box. You can use Boolean operators in your search. Other options are available from the search screen as shown below.



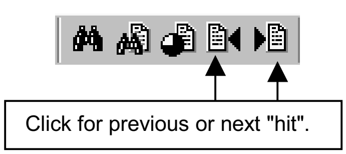
SEARCH RESULTS

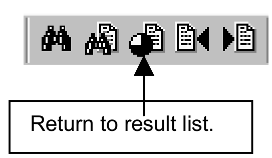
From the Search Results box, double click on a file or select a file and click on View. The circles on the left indicate the relevance ranking.



NAVIGATE THE SEARCH RESULTS

Navigate the search with the icons in the toolbar. Search criteria is highlighted. You can return to the result list or move to the next or previous "hit". You can move from "hit" to "hit" across files.





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Contents

1. Introduction to the CD-ROM Edition

This revision and updating of the first edition, which was published in 1985 by Garland Publishing in New York, contains some 4,800 bibliographical entries with annotations. It is intended as a guide to the history of mathematics. The enormous growth in the literature in the past fifteen years is reflected in the fact that this edition, in spite of being very selective, has twice as many entries as the first. Of these, 2,800 are entirely new while many of the remaining ones have been updated.

Thirty-eight historians of mathematics from ten countries have participated as contributing editors. It has been a privilege to work with these experts—each recognizing the value of gaining a mastery of the literature and each showing a ready willingness to share the benefits of that mastery with others. They have provided the paths by which anyone who wishes to enter into the history of mathematics can begin to thread their way through the massive body of literature represented in the various comprehensive bibliographic databases that are available today.

In order to play this guiding role the editors have been selective—trying to combine a sample of the best scholarship with the best introductions and the most important initial points for a given topic.

Since the rationale for this bibliography as well as its basic design have remained unchanged from the first edition, it seems appropriate to refer for fuller information to that introduction, which (with slight modifications) has been reproduced here. In it Joseph W. Dauben has also given a vivid picture of the particular task that a chief editor faces.

The first edition was dedicated to the memory of Kenneth O. May, an influence on both Dauben and myself. One of May's interests was subject-retrieval systems for mathematics and for the history of mathematics. Computers have helped but not yet entirely solved the subject classification and retrieval issue that May described in the days of card indexes in his *Bibliography and Research Manual of the History of Mathematics* (1973; item **14**). An item such as **3389**, which deals with numeration systems of eighteenth-century American Californian Indians, could be placed in a number of sections in addition to the Numbers and Number Theory section where it is situated. Unfortunately, even with the aid of computer technology, designing and implementing a subject classification scheme which could retrieve any such item by any of its relevant subject terms has been beyond the resources of even this selective bibliography.

Computers have definitely helped in the preparation of the text and in the communication between all the people who have worked on it from conception to final production. The only drawback has been that participating fully in the work required ready access to computers and an e-mail capability, and these are not yet available uniformly world-wide.

1.1. Acknowledgements. As the one most aware of the great indebtedness to others in producing this work I am glad to be able to express gratitude to them. The largest share of credit goes to the contributing editors and the following people whose expertise has made this edition possible.

Joseph W. Dauben, who conceived and produced the first edition so successfully, saw the need for an updating. I readily agreed to take this on when asked in June 1992, though we had no publisher at that point. The International Commission on the History of Mathematics continued as the sponsor.

Keith Dennis, then Executive Editor of *Mathematical Reviews*, was searching for bibliographies to turn into electronic form when he learned about the project in January 1995. He proposed it to the American Mathematical Society, and it was approved by the appropriate committee and the agreement finalized in February 1997 as a joint AMS–ICHM project. Donald G. Babbitt, Publisher, and John H. Ewing, Executive Director, represented the AMS in the agreement, and Eberhard Knobloch of the Technische Universität Berlin represented the ICHM as the Chair of its Executive Committee. The encouragement given by all of these initial contacts was especially appreciated considering that the AMS had not before taken on a CD-ROM work entirely in-house.

On the AMS side, the design of the textual database structure and accompanying TeX program was done by Ron Whitney. Lisa Hanselman did the keyboarding of the first edition. Vickie Ancona oversaw the proofing of the data. Dennis and his colleagues at *Mathematical Reviews*, Patrick D. F. Ion and Bert TePaske-King, helped check the resulting files and provided detailed helpful suggestions throughout the planning and conversion stages. Tom Blythe and Neil Bartholomew were members of the technical team. Ralph Sizer and Pat Zinni were members of the production team. Linda Guccione designed the interface and was instrumental in identification of functionality for the product. Siulam Fernandes designed the cover. Karen Ferreira, Director of Electronic Product Development, got the project off and running, and Wendy Bucci, as project leader, brought everything together for the final product.

Sheila Turcon of McMaster University, Canada, did initial copy editing of all the new material and helped to combine it with the first edition.

David Zitarelli of Temple University, Philadelphia, through his leadership of the abstracts section of the journal *Historia Mathematica* from 1988 to 1999, provided a major resource for the contributors to this bibliography.

From the beginning of the venture Bruce Chandler of the College of Staten Island (CUNY) and Ivor Grattan-Guinness of Middlesex University have been valuable advisers.

Albert C. Lewis
Charles S. Peirce Edition Project
Indiana University–Purdue University, Indianapolis

2. Introduction to the First Edition

> Bibliographic extravagance is a sin rather than a virtue, a real perversity. *George Sarton*

George Sarton liked to describe the history of science as a "secret history", and the history of mathematics as the secret within the secret, for while most scholars might know something of the history of science in general, few mathematicians, scientists, or even specialists in the history of science could be expected to know much about the history of mathematics. In part, this was because of the theoretical and often abstruse nature of mathematics, but also in part because so little had been done to make the history of mathematics accessible to those who might have need of it, or to others who might simply be interested in learning more about it. A major goal of this bibliography in the history of mathematics is, in fact, to furnish a reference work that will help to open the doors to this *secreta secretorum*, and to provide something of an Ariadne's thread through the labyrinth of this increasingly specialized and often difficult domain of human knowledge.

2.1. The History of Mathematics. Mathematics has a history that begins in *pre*-history. The earliest archaeological and anthropological evidence we possess makes it clear that even as *homo sapiens* began to speak, he began to count as well. Much before there was any way to express even the simplest numbers in written form, man was counting and calculating. By the time neolithic cultures had emerged along the rivers of the Tigris-Euphrates, Nile, Hwang Ho, and Indus, mathematics was already developed and in some cases to a high and sophisticated degree. This was especially true in Mesopotamia, where the Babylonians developed algebra to a considerable extent and devised a very powerful sexagesimal (base-sixty) arithmetic which was well suited to their complex but correspondingly effective mathematical astronomy. For the most part, however, ancient knowledge of arithmetic, algebra, and geometry was imperfect or only approximate and was reserved for the small numbers of royal scribes and priests who became adept at solving basic problems in accounting, surveying, and astronomy, often with mystical and religious overtones. The Egyptian *Book of the Dead* makes this quite clear in describing a Pharaoh who knows a mnemonic device, learned in the form of a rhymed chant, to remember how to count from one to ten on his fingers. His ability to do so is considered sufficient to establish that he is indeed a king with full knowledge of things reserved for the gods, thereby convincing the ferryman to transport him across the river of forgetfulness to the divine world of eternal life.

Centuries later, the Greeks of the archaic period began to "demythologize" their world (to borrow Henri Frankfort's phrase) and adopted both a more secular and objective perspective on nature than did their predecessors, the Egyptians or Babylonians. But they also succeeded in elevating mathematics to the idealized realm of perfect, eternal knowledge, whose truths were associated with the loftiest philosophical ideals. The Greeks, having learned their mathematics from the Egyptians and Babylonians, soon transformed it into a powerful epistemological tool. From Thales to Euclid numerous discoveries were made in geometry and arithmetic. Equally important, methods were developed to *prove* the validity of an assertion or mathematical theorem. This, of course, culminated in two major achievements—Aristotle's formal logic of the syllogism and Euclid's axiomatic geometry. By this time the practical importance and theoretical significance of mathematics was also clear not only to philosophers and mathematicians, but to shopkeepers, mariners, generals, and government administrators. Moreover, mathematics had found its first true historian (of whom any record survives)—Eudemos of Rhodes, a disciple of Aristotle who wrote a summary of Greek mathematics in the early 4th century (fl. 335 B.C.).

For the rest of antiquity the Greek advances remained the norm, and for over 900 years few advances were made. Despite nearly a millennium of the so-called Dark Ages, mathematics eventually experienced a *second* miracle, as George Sarton called it, that is, the interest of Arab scholars first in discovering and preserving the mathematics of the ancients and then in augmenting and transmitting that knowledge. In so doing, they transformed and invigorated much of the received mathematics. They also developed the Hindu-Arabic decimal system, a seminal discovery that eventually was transmitted to the Latin West.

Both the Arabic and Latin traditions were particularly strong, and much richer than is usually thought, largely because until recently little in the way of systematic research to produce viable texts and informative commentaries was available to historians of science. When Gustav Eneström began publishing corrections in the 1890s in *Bibliotheca Mathematica* (item **24**) to the monumental *Geschichte der Mathematik* (item **891**) of Moritz Cantor, the areas most often found wanting were those for ancient, Islamic, and medieval mathematics. Since 1900, these areas have received considerable attention, and recent research reflects strong interest now in each of these periods. Such activity is well represented in this bibliography, with substantial sections devoted to Egyptian, Babylonian, Greek, and medieval mathematics of the Indian, Islamic, Hebrew, and Western Latin cultures.

The most important stage in the advance of European mathematics coincided with the Italian and Northern Renaissance of the fourteenth and fifteenth centuries, when the progress of mathematics and the sciences generally was as rapid as the social and economic development of Western Europe. Beginning with 1600, this bibliography proceeds by roughly 100-year intervals (although a certain amount of overlap between centuries is unavoidable) as it surveys the development of mathematics from the Renaissance through the 17th, 18th, 19th, and 20th centuries.

In the last hundred years, mathematics has developed into a highly abstract and esoteric body of knowledge which, nevertheless, has extraordinary versatility in applications that permeate almost every aspect of life in any modern society. Its past history, as already indicated, is enormous, from its beginnings evident in the notched bones of caveman tally sticks to, more recently, the sublimities of group theory, abstract algebra, and the powerful applications of differential equations and high-speed computers. In fact, the last two major divisions of this bibliography investigate the history of mathematics by 22 subject areas, ranging from the philosophy and sociology of mathematics to mathematics in Africa and the Orient, as well as the subject of women in mathematics.

One way to bring order to this long, diverse, and complicated history of mathematics, however, is through the guidance of a good critical, annotated bibliography.

2.2. The Role and Significance of Bibliographies. The art of compiling bibliographies is nearly as old as the history of written documents themselves.[1] It is

[1]The information contained in this section of the Introduction draws heavily from Archer Taylor, *A History of Bibliographies of Bibliographies* (New Brunswick, N.J.: The Scarecrow Press, 1955); Louise N. Malclès, *Bibliography*, trans. T. C. Hines (New York: The Scarecrow Press,

of interest to historians of science that the first bibliographies of which any record is known were drawn up by the Roman physician Galen in the second century A.D. They are his *De libris propriis liber*, followed by a second version, the *De ordine librorum suorum liber* (which survives only in a fragment), both of which were intended to authenticate his own works and distinguish them from the many spurious writings attributed to him. Later bibliographies in antiquity and the early medieval period, like those of St. Jerome and the Venerable Bede, fall into the tradition of compiling lists of ecclesiastical authors and their works.

The first bibliography encompassing printed works rather than manuscript material was compiled in the 15th century by Johann Tritheim, whose *Liber de scriptoribus ecclesiasticis* (1494) continued in the tradition of Jerome and Bede. None of these works, however, whether of books or manuscripts, was actually called a bibliography—the words used most often were those like "bibliotheca," "catalogus," "repertorium," "inventarium," or "index." The word "bibliography" was actually used first in France, it seems, by Gabriel Naudé, secretary and librarian to Cardinal Richelieu, for his *Bibliographia politica*.[2]

Bibliography actually came into its own in France, although slowly. The word is absent from the first edition of the *Dictionnaire de l'Académie Française*, and was still missing in 1751. Nor does it occur in Diderot and D'Alembert's *Encyclopédie* (although the term "bibliographer" does, but only in the sense of one skilled in the use of ancient manuscripts, e.g., a paleographer; there is no reference to catalogues or lists). In the fourth edition of the Académie's *Dictionnaire*, however, "bibliography" in the modern sense, finally appears.[3]

It was the French Revolution, however, that marked the real turning point in the history of bibliography. In fact, the subject became a matter of considerable urgency and was the special subject of a "Rapport sur la bibliographie" issued on 22 Germinal of the Year II of the Revolution (April 11, 1794). Not only was this the first official document of a government on the subject of bibliography, submitted by Henri Grégoire (1750–1831), the constitutional Bishop of Blois and a Deputy of the Convention, but it addressed directly the problem of cataloguing the mass of books confiscated from religious organizations and emigres, all of which subsequently became the property of the French nation. It was also in France that the subject was first institutionalized, at the Ecole des Chartes, where a professorship was established for bibliography in 1869. Courses were regularly offered, chiefly on the classification of archives and libraries.

As for bibliographies of interest to the history of mathematics, one of the first is attributed to Cornelius à Beughem, a book-seller and publisher who lived for a long period in Emmerich, Westphalia, and who produced a number of specialized

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1961); Georg Schneider, *Theory and History of Bibliography* (New York: Columbia University Press, 1934), especially pp. 3–24; John Thornton and R. I. J. Tully, *Scientific Books, Libraries and Collectors* (London: Library Association, 1954); and Theodore Besterman, *The Beginnings of Systematic Bibliography* (London: Humphrey Milford for Oxford University Press, 1935).

[2] G. Naudé, *Bibliographia Politica* (Venice: F. Baba, 1633); also issued in French as *La bibliographie politique* (Paris: G. Pelé, 1642). Strictly speaking, however, the word "bibliography" was also used in 1645 by Lewis Jacob de Saint Charles, but in a different sense from that currently understood. Jacob used the word to signify the mechanical writing and transcription of books. See Philip H. Vitale, *Bibliography, Historical and Bibliothecal* (Chicago: Loyola University Press, 1971), p. 14.

[3] *Le Dictionnaire de l'Académie française* (Paris, J. B. Coignard, 1694; reprinted Lille: L. Danel, 1901; fourth edition, 1762).

bibliographies, including one in 1688 entitled *Bibliographia mathematica et artificiosa novissima*, which ran to nearly 500 pages and included the works of nearly 2000 writers.[4]

Not until the 19th century, however, was any real impetus given to the systematic production of bibliographic resources. These were naturally stimulated by the progress of public education and the proliferation of universities, learned societies, and related institutions. Stabilization of the book trade, the growth of periodical presses, and the establishment of the first great public archives and libraries all provoked an obvious need for systematic bibliography. For the first time, rather than trying primarily to record, note, or save from oblivion the works of the past, the role of bibliography advanced to one of dissemination, calling to the attention of scholars and interested readers the most current advances in learning. Here, not surprisingly, leadership came first from Germany. The organization of universities and their emphasis upon careful scholarship made the creation of research libraries essential, and these in turn both depended upon and stimulated the subject of bibliography. If one surveys the major bibliographies produced in this period, and especially those of interest to the historian of mathematics, an instructive pattern emerges:

1830. I. Rogg. *Bibliotheca Mathematica* (Tübingen).

1839. J. O. Halliwell. *Rara Mathematica* (London).

1847. A. de Morgan. *Arithmetical Books from the Invention of Printing* (London).

1854. L. A. Sohncke. *Bibliotheca Mathematica* (Leipzig).

1863. J. C. Poggendorff, ed. *Biographisch-literarisches Handwörterbuch* (Leipzig).

1868–1887. B. Boncompagni. *Bulletino di Bibliographia e Storia delle Scienze matematiche e fisiche* (Rome).

1873–1928. P. Riccardi. *Biblioteca matematica italiana* (Modena).

1873. A. Erlecke. *Bibliotheca Mathematica* (Halle).

1884–1914. G. Eneström, ed. *Bibliotheca Mathematica* (Stockholm).

Among these works, the most significant, even today, remains the seminal contribution of J. C. Poggendorff, an historian, biographer, and bibliographer. At age 27, he became editor of the *Annalen der Physik und Chemie* (founded in 1790) and, as a result, initiated a correspondence with the leading scientists of his day. This eventually prompted a project that was naturally suited to his historical interests (also expressed in his lectures and in a book on the history of physics), namely, the *Biographisch-literarisches Handwörterbuch zur Geschichte der exakten Naturwissenschaften.* In 1863 it consisted of only two volumes, comprised primarily of brief biographical information and bibliographic references for 8400 scientists up to 1858. By 1974, however, the continuation of this series had grown to 18 volumes.

Mention should also be made of Baldassarre Boncompagni, who even established his own private printing plant in order to ensure the high standards of his publications related to the history of science. Especially important is the *Bullettino Boncompagni*, which George Sarton once described as "a very rich collection, a model of its kind."[5] Another of those dedicated to bibliography and the history of mathematics before this century was Gustav Eneström, who began his career as

[4] Cornelius à Beughem, *Bibliographia mathematica et artificiosa novissima* (Amsterdam: J. à Waësberge, 1688).

[5] *Isis* 2 (1914), 133.

a librarian. Although little is known of his private life, one biographer has called him "very original and eccentric."[6] Perhaps no greater tribute could be made to Eneström's contributions to the history of mathematics than one paid by George Sarton in 1922: "Personal notes for living scholars have been thus far avoided in *Isis*, but an exception must be made in favor of Gustav Eneström, than whom no one has ever done more for the sound development of our studies."[7]

More recently, George Sarton's guides to the history of science set a new generation on a more interdisciplinary and historical course. Of special interest to users of this bibliography is Sarton's *The Study of the History of Mathematics* (item **42**), published in 1937 and devoted, in part, to a discussion and critique of bibliographic resources on the subject. Sarton's work was followed a decade later, in 1946, by Gino Loria's *Guida allo studio della storia delle matematiche* (item **40**). This too provided excellent critical discussion of the history of mathematics, with the advantage that it was able to profit from the appearance of Sarton's guide as well.

Shortly after the appearance of Loria's guide, George Sarton published *Horus*, a major effort on his part not only to provide a rationale for the purposes and meaning of the history of science (Part I of *Horus*), but a bibliographic summary as well, meant "to provide a kind of *vade mecum* for students" (Part II). "The first part is meant to be read," Sarton wrote, "the second to be used as a tool."[8] In his introduction to Part II, Sarton asserted that "nothing is more instructive than a good bibliography... Every bibliography must begin with a bibliography, and it must end with a better bibliography."[9]

The most recent of all the bibliographic guides concerned with the *history* of mathematics, however, is Kenneth May's (item **14**). Its aim was "to assist mathematicians, users of mathematics, and historians in finding and communicating information required for research, applications, teaching, exposition and policy decisions."[10] May's bibliography was inspired, in part, by the rampant growth of literature related to mathematics, which he estimated in 1966 as already consisting of half-a-million titles and growing at the rate of 15,000 new items annually. May was particularly concerned that "this enormous collection is not indexed. No one knows its nature or contents. Preliminary studies suggest that there is a vast amount of duplication, and that the important information is contained in perhaps as little as 10% of the titles."[11] In order to reduce this problem and obtain what he called "effective entry to this storehouse so as to find information, orientation, and enlightenment," May's bibliography offered 31,000 entries under 3700 topics, with an appendix listing about 3000 periodicals in which papers on mathematics and its history are published.

2.3. Bibliographies and Information Retrieval. Recently, some scholars have sensed an impending crisis in the domain of information retrieval. Within the past decade, most major libraries, universities, and publishers have begun to rely on computerized indexes and reference systems to facilitate data management. Some

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[6] W. Lorey, "Gustav Eneström (1852–1923)", *Isis* 8 (1925), 314.

[7] G. Sarton, "For Gustav Eneström's 71st Anniversary", *Isis* 5 (1922), 421.

[8] G. Sarton, *Horus* (Waltham, Mass.: Chronica Botanica, 1952), p. ix.

[9] *Ibid.*, p. 71.

[10] K. O. May, item **17**, p. iii.

[11] K. O. May, "Growth and Quality of the Mathematical Literature", *Science* 154 (1966), 1672–1673. See also his article with the same title in *Isis* 59 (1968), 363–371.

fear that soon we shall be so inundated with the printed word that even attempting to do basic research on a given subject will be a bibliographical nightmare. Automation may indeed help to solve some bibliographical problems, but it may also contribute to the problem by facilitating even more rapid production of the written word and of information in general.

Not all agree, however, and among the most persuasive of the dissenters is Yehoshua Bar-Hillel, who more than twenty years ago posed the question, "Is information retrieval approaching a crisis?" In Bar-Hillel's opinion, there is no crisis. Simply because the growth of mathematical information may seem to be pathologically out of control (to adopt a point of view made popular by Derek de Solla Price) does not mean that researchers will wallow in a hopeless miasma of printed material, making it impossible for anyone to keep abreast of the latest books, monographs, papers, and articles on a given subject. Bar-Hillel observes that:

> Scientists did not spend on the average in 1961 more time on reading than they did 12 years ago, though printed scientific output has indeed almost doubled during this period. There must therefore have been a way out between the horns of the dilemma. What is it? Everybody knows it: *Specialization*.[12]

Nonetheless, as research becomes increasingly focused, bibliographies become all the more important, especially for those who choose to move from their own areas of specialization into others that may be related, or even wholly new. Here bibliographies play a crucial role in helping to orient new readers to a field in which they may be less than proficient.

There is another service bibliographies perform, and this is related to facilitating research and helping to reduce duplication of efforts. Not long ago it was suggested that hundreds of thousands of dollars (estimates ranged from $200,000 to $250,000) had been wasted because a Russian paper on Boolean matrix algebra and relay contact networks was not known to American researchers. According to an article in *Science*, the Russian paper had appeared in an "important, readily available Soviet journal" and "simply reposed on a library shelf waiting to be noticed."[13] This example had been noted as early as 1956, when William Locke wrote in *Scientific American*, "groups of people in several companies in the United States did, in fact, work for five frustrating years on the very points cleared up by this paper before discovering it."[14] The paper in question was written by A. G. Lunts (also transliterated as Lunc) in 1950: "The Application of Boolean Matrix Algebra to the Analysis and Synthesis of Relay Contact Networks," but published in Russian. The waste of both time and money suggested by this example was even brought to the floor of Congress as an example of costly duplication and inefficiency of research efforts due to lack of proper information dissemination.[15]

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[12] Y. Bar-Hillel, "Is Information Retrieval Approaching a Crisis?" Chapter 20 of *Language and Information. Selected Essays on Their Theory and Application* (Reading, Mass.: Addison-Wesley, 1964), p. 365.

[13] Ralph E. O'Dette, "Russian Translation", *Science* 125 (March 29, 1957), 579–585; especially p. 580. At the time, R. E. O'Dette was Program Director of the Foreign Science Information Program of the National Science Foundation.

[14] William N. Locke, "Translation by Machine", *Scientific American* 194 (January 1956), 29–33, especially p. 29. Locke was working at MIT in the Department of Modern Languages when he wrote this article.

[15] See A. G. Oettinger, "An Essay in Information Retrieval or the Birth of a Myth", *Information and Control* 8 (1965), 64–79. Oettinger argues that the deleterious effects of the so-called

The thrust of Locke's article in *Scientific American* was simple: an inexpensive means of translating material from Russian to English should be made available so that such a waste of time and money could be avoided in the future. Ironically, as a letter published in the March issue of *Scientific American* noted, the Lunts paper should have been known already, since it had been abstracted in *Mathematical Reviews*.[16] As R. P. Boas, Jr., also pointed out in a letter to *Science* (Boas was then executive editor of *Mathematical Reviews*): "If people are unable or unwilling to use the bibliographic aids that are already provided, there is little point in supplying them with even more in the form of translations and so on."[17] E. H. Cutler posed an equally germane question. Because the article by Lunts had been annotated in *Mathematical Reviews*, he asked, "Does not the case suggest more the need for the application of machines to the bibliographic problems of cross-referencing publications rather than the more fascinating application to the problem of translation?"[18] Locke agreed. On the same page of the March issue of *Scientific American*, he noted that "My example does show the need for machines to keep the bibliographies of specialized fields up to date."

Whether or not machines are used to store, catalogue, and retrieve bibliographic information, there are many ways in which bibliographies, whatever their form, are essential resources for serious research. Not only does a good bibliography eliminate the need to read everything on a given subject—clearly impossible with the overwhelming number of publications produced annually in mathematics, not to mention the burgeoning growth of literature in the *history* of mathematics—but it ought to provide a simple way of orienting the user to the most significant works in print on a particular topic.

Another and often unappreciated value of bibliographies is the extent to which they are historical and sociological resources in their own right. This, in fact, was the point made in 1952 by Victor Zoltowski in an article entitled "Les cycles de la création intellectuelle et artistique" in *Année sociologique*, and quoted by Louise Malclès to the effect that "the gifts of bibliography are capable of leading to the discovery of cycles of intellectual and artistic creation." As Malclès says, "Just as the demographer inventories populations, and studies their movements, without knowing each citizen of the country in question, the bibliographer, without having read all books, follows their creation, their purport, and distribution."[19]

What sets this annotated bibliography apart is that all entries *have* been read critically and annotated by experts. This means that readers have at their disposal those works regarded as essential by specialists in a large number of different areas of the history of mathematics. From these, it is a far simpler task for researchers to compile increasingly detailed bibliographies of their own, with the knowledge that the most essential material on a given topic appears here as a starting point.

Insofar as trends or cycles of intellectual interest might be discerned from reading this bibliography, it may be of interest to contrast it briefly with the only other

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information explosion are greatly exaggerated, and that the incident involving the Lunts paper is really a "comedy of errors" occasioned by "overzealous proponents in the area of information retrieval," as characterized by A. J. Lohwater in his review of Oettinger's essay in *Mathematical Reviews* 29 (6) (June 1965), #6960.

[16] *Mathematical Reviews* 11 (September 1950), 574.

[17] *Science* 125 (June 21, 1957), 1260.

[18] *Scientific American* 194 (March 1956), 6.

[19] Malclès, op. cit., p. 8.

major bibliographic reference work to appear for the history of mathematics in the last decade, namely, Kenneth O. May's *Bibliography and Research Manual of the History of Mathematics* (item **14**). As early as 1966 May had written a short article for *Science*, in which he discussed the problems raised by the fact that the annual list of publications in mathematics was growing rapidly.[20] May's solution was a project he did not complete until 1973—his *Bibliography and Research Manual* (and even then, it was not really finished, for he continued to update it until his death in 1977). May's *Bibliography* remains an important reference work for the history of mathematics in all periods and subjects. What sets it apart from this bibliography, however, is the fact that it lacks annotations and is now more than ten years out of date. The number of articles which have appeared in new journals like *Historia Mathematica* (founded in 1974), and the number of serious book-length biographies and special histories of specific branches of the history of mathematics (not to mention the stimulus given to all areas of the history of science by the monumental *Dictionary of Scientific Biography*, item **8**), show the extent to which the history of mathematics has become professionalized in its own right as a subject for serious study in the last ten years.

2.4. Special Aspects of This Bibliography: Caveats and Comments. Ralph Waldo Emerson once quipped that consistency was the hobgoblin of small minds. Users of this bibliography should probably keep that in mind—along with George Sarton's equally sardonic statement that bibliography was "a sin ... a real perversity." By this he meant that some researchers elevate bibliography to the point where it appears to take precedence over everything else, including the subject matter. However, Sarton was very much aware of the need and crucial contribution that good bibliographies make to professionals and amateurs alike, for Sarton was a consummate if idiosyncratic bibliographer. But he disdained, above all, mere lists of titles, however long, as ends in themselves. Such lists he termed "bewildering" (Sarton, item **48**, p. 26). Bibliographies took on greater value when annotated, constructed in such a way that expert understanding might guide newcomers to a particular subject.

Each section of this bibliography reflects a considered judgment as to what works are absolutely essential on any given topic or period, accompanied with critical descriptions of those works. Emphasis has been given to the most useful and authoritative secondary sources and, when appropriate, to texts, manuscripts, correspondence, and other varieties of primary sources. Reviews of major items have also been included, especially when they warn readers of special quirks, problems, or prejudices in a given item, or provide substantive additional information relevant to a given subject. Older standard works that have established themselves as a continuing part of the history of mathematics are also, of course, included. The major European languages, especially French and German, are essential tools for the historian of mathematics, and no attempt has been made to minimize the frequency of their appearance in this bibliography. References in other languages, however, are included only when thought essential, but titles in Italian, Spanish, Russian, Chinese, and Japanese have been listed whenever appropriate. Where English translations or their equivalents exist, these have been noted. Finally, truly obscure studies, unless thought crucial, have been minimized in favor of more easily available sources, but not always.

[20] See above, note 11.

Although most entries are annotated, some are not, if in the opinion of the reviewer the title accurately reflects the content of the reference. In other cases, where an item has appeared elsewhere in the bibliography with sufficient annotation, only a cross-reference has been given. However, if a work is important for differing reasons to more than one section, it has been repeated (again with cross-references), but with a separate annotation tailored specifically to the relevance of the work for the section in which it appears.

Ultimately, in editing this volume I have adopted as pragmatic a position as possible; the final consideration has always been to make this as useful a reference work as possible. Because of the large number of individual contributors, however, it has not always been possible to attain complete consistency in the format and amount of information supplied for each title. Although format guidelines were issued to all contributors, not everyone chose to follow them exactly or consistently. Where practicable, the editor has brought as much uniformity of format to references as possible, but there were limits to which additional information could be retrieved. In most cases what discrepancies remain are of little consequence; the one exception is in the case of different editions of a given work. Some contributors have tried to be as inclusive as possible, indicating the significance between editions, or at least noting the number of different editions of a given work and their dates. Some have preferred to supply the first, others only the most recent edition. Readers should therefore be aware that it is always wise to make their own bibliographic searches to discover which editions or versions of a work may be available to them, as well as the number and differences among various reprintings and editions of a given work. (Usually this can be done most easily by referring to the National Union Catalog of the Library of Congress.)

A major orthographic dilemma facing any bibliographer dealing with material in multiple languages is, of course, the different possible spellings and transliterations of a title or author's name. This is most acute for citations in Russian, Japanese, Chinese, and Arabic. One notable example in this bibliography is that of A. P. Youschkevitch, whose name variously appears in some references as Juschkewitsch, Juškevič, Juschkevic, Youskevich, or Youschkevitch. The practice that has been followed in all cases here is to present a given name *as it is spelled on the title page of the work in question.* Thus, one will find item **2242** listing "Youschkevitch," with item **1503** as "Juschkewitsch," one reflecting a French, the other a German translation. In the indexes at the end of the book, however, all are cross-referenced to the canonical spelling that has been otherwise adopted in this bibliography, namely, "Youschkevitch." Other but less complicated cases of variant transliterations include "Bashmakova," "Kowalevskaya," and "Lobachevsky."

Similar variations occur in the case of Greek names. Here the practice has been followed of giving names in terms of transliterations of Greek spellings, e.g., Diophantos. However, in all citations, names are always given as they appear on *title* pages, which often follow earlier convention and use the Latinized version of Greek names, e.g., Diophantus.

2.5. Conclusion. Why would anyone wish to undertake a project such as this one? My own reasons have been both professional and personal, but before saying more, I would like to dismiss one motive for undertaking bibliographic research that has been attributed to George Sarton. Marc De Mey, writing in the 1984 Sarton memorial volume of *Isis*, interprets Sarton's penchant for bibliography in very psychological terms. What interested De Mey was that Sarton's interest in bibliography seems to have antedated his interest in the history of science. Based upon a letter that Sarton sent to the Chief Librarian of the University of Ghent, dated November 4, 1902, De Mey conjectures as follows:

> If, as in classical embryology, the order of formation is taken as an indication of primacy (here intellectual), it is obvious that Sarton's interest in bibliographies is more basic than his interest in science to which he, only several years later, applied this attitude in so masterly a fashion. Confronted with such a vigorous need, one feels compelled to take certain psychoanalytic claims seriously and search for the sources of this attitude in early childhood. It seems almost a textbook case. The lonely child George Sarton, losing his mother at a very early age, starves, in May Sarton's words, for the tenderness that vanished with her. Deep insecurity could derive from lesser causes. The collector's attitude is considered a classical response to such insecurity: if life, on the whole, is uncertain, establishing and controlling a well-organized and complete collection of items belonging to a specific domain provides solidity and certainty for one subrealm at least. That attitude is later enthusiastically extended to science as the most solid domain. This is one plausible suggestion, but there might be others. In any case, if one were to engage in a study of Sarton along the lines that Erik Erikson applied to Martin Luther, Sarton's bibliographical bias should play a pivotal role, since in its fervor it comes close to the "obsessive compensation" characteristic of many great achievements.[21]

I doubt that any of the contributors to this annotated bibliography would wish to see it in terms of "obsessive compensation"! In fact, this should remind us of Sarton's *own* phraseology, as well as his caveat, that bibliography was "a sin... a real perversity." Surely this puts the lie to De Mey's interesting if arcane speculation, because Sarton, in the best sense of this bibliography, saw such guides as practical sources of information.

Despite the valiant efforts of the copy editor, it has not always been possible to fill certain gaps. Sometimes publishers' names could not be found, or issue numbers of periodicals within a given volume could not be identified. From time to time the National Union Catalog of the Library of Congress was inaccurate, or its information incomplete. Although I have attempted to bring an overall uniformity to the format of the citations, and to check them all for completeness, I have also tried to resist letting this become a bibliographic obsession. On the other hand, what *has* been an uncompromised goal is to make certain that each citation provides the essential information necessary to retrieve it from libraries or book sellers with relative ease.

My own reasons, as just indicated, for undertaking this project have been to some degree personal, and to a larger extent professional. Kenneth May was both a friend and a moving force in my own interest in the history of mathematics. This bibliography, for me, honors the efforts he made, especially through *Historia Mathematica*, to promote the subject in the most professional and international way

[21] Marc De Mey, "Sarton's Earliest Ambitions at the University of Ghent", *Isis* 75 (276) (1984), 42.

possible. But it was primarily because I felt a strong need for such a bibliography that I was ultimately persuaded to undertake this project.

Actually, when Robert Multhauf and Ellen Wells first approached me about editing a volume on the history of mathematics for their Bibliographies on the History of Science and Technology series, I was doubtful whether any single individual was capable of surveying the entire history of mathematics from antiquity to the present in any sort of authoritative way. I agreed, however, with their basic premise: authoritative, annotated bibliographies in the history of science would be of great utility to the scholarly community. With this in mind, it seemed reasonable to suggest that a collaborative effort might be the perfect solution, involving a dozen or so experts who might reasonably be expected to cull the best forty or fifty titles in a given area, and provide annotations within a few months. As the editor of *Historia Mathematica* I was in close contact with leading authorities on virtually every aspect of the history of mathematics. Given assurances that this would be fine, I wrote to several dozen colleagues and modestly proposed (with what in hindsight was too much optimism) that if all were willing to draw up basic lists of essential works in their special fields, a preliminary draft of the bibliography might be possible within six months, with a completed annotated version in print within a year.

My initial letter was answered with a variety of responses. The majority of those to whom I wrote, I am happy to say, responded positively, even enthusiastically. Most recognized a definite need for such a critical bibliography to serve the interests of the history of mathematics and, furthermore, they were willing to take on the job without remuneration, for the sake of the subject and its future. Most agreed that they could comply with my request for preliminary lists within six months. This would allow time to check all of the proposed bibliographies for duplication, cross-reference them as needed, and thereby prevent unnecessary duplication.

The present volume is the result of an extraordinary amount of effort. It could never have been accomplished by a single person, but required the combined efforts of all those contributors who worked together in the best cooperative spirit of scholarly collaboration. This would have pleased Kenneth May greatly, and it is both fitting—and a reflection of the magnanimity of the many scholars who have contributed to this bibliography—that all royalties accruing from its publication will be used to establish a fund in his memory. This fund, in the names of all contributors to this volume, is to be administered by the International Commission for the History of Mathematics, and will be designated specifically to help promote the history of mathematics internationally.

I especially want to acknowledge the continuing help and moral support of three individuals in particular: Robert Multhauf for his persistent encouragement along the way; David Rowe for his diligence in helping to complete and proofread the final version of the bibliography; and Rita Quintas for her care in seeing this volume through the last editorial stages of its production. Moreover, I am happy to express my indebtedness and gratitude to all of the contributors to this volume, not only for their care in producing each of the individual sections, but for their patience owing to the time it has taken to cement the myriad pieces into a coherent and useful whole.

The ultimate goal of this bibliography has been to make the *secreta secretorum* of the history of mathematics much less a secret history than it may seem to many at present. I am grateful to all who have given so generously of their time and energy in order to make this reference work possible.

JWD

3. Contributing Editors and Subject Areas

A contributor's principal subject areas (jointly worked on in some cases) are listed after name and affiliation. The symbol * indicates contributions to the first edition (1985) and + indicates those to the present edition. A deceased person is indicated by †.

Since the chief editor has re-classified and modified some entries of almost every section of the bibliography in the interests of general consistency, any flaws should be assumed *prima facie* to be his responsibility.

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Summary: A selected bibliography on the history of mathematics. Contains over 4,800 bibliographic entries with annotations.

ISBN 0-8218-0844-3

1. Mathematics—History—Bibliography. I. Dauben, Joseph Warren, 1944– . II. Lewis, Albert C. III. International Union of the History and Philosophy of Science. International Commission on the History of Mathematics. IV. American Mathematical Society.

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I. GENERAL REFERENCE WORKS

The following works include general reference sources of particular utility for historians of mathematics. Readers with specific interests are referred to the separate sections of this bibliography dealing with individual time periods or topics. Moreover, it should also be noted that the reference works annotated here have been selected for their specific utility in the *history of mathematics*, and by no means exhaust the tools available for scholarly research. Many additional reference works are also of great use, including general guides to archives and other library resources, encyclopedias, historial dictionaries, dissertation abstracts, and government publications. Although such materials are not included here, they should always be kept in mind and are listed in the following guides.

1. Sheehy, Eugene P., ed. *Guide to Reference Books*. 10th ed. Chicago: American Library Association, 1986; Supplement, 1992.

   Covers up to 1990.

2. Mullay, Marilyn and Priscilla Schlicke, eds. *Walford's Guide to Reference Material*. Vol. I: *Science and Technology*. 7th ed. London: The Library Association, 1996.

DICTIONARIES, ENCYCLOPEDIAS, AND BIBLIOGRAPHIES

3. Archibald, Raymond Clare. "Bibliographia de mathematicis". *Scripta Mathematica* 1 (1932–1933), 173–181, 265–274, 346–362; 2 (1933–1934), 75–85, 181–187, 282–292, 363–373; 3 (1935), 83–92, 179–190, 266–276, 348–354; 4 (1936–1937), 82–87, 176–188, 273–282, 317–330.

   Bio-bibliographical notices of some 200 mathematicians, mostly of the twentieth century. Indexed.

4. Bynum, W. F., E. J. Browne, and R. Porter, eds. *Dictionary of the History of Science*. London: The Macmillan Press, 1981. Reprinted Princeton, N.J.: Princeton University Press, 1985.

   Unlike dictionaries of scientific biography, the organization of this dictionary is conceptual. It includes more than 700 entries explaining the origins, meaning, and significance of major theories and ideas in the history of science, including mathematics. The emphasis is on Western science over the last 500 years, with particular attention to current historiography and philosophy of science. Each of the major entries has its own bibliography. There is also an index of all scientists mentioned and extensive cross-referencing.

5. *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*. Leipzig: B. G. Teubner, 1898–1935. 6 vols. in 23 parts. Parts of a second edition appeared as *Encyklopädie...*, 1939–1958.

   Long articles by specialists with full bibliographic notes. A French edition of the original set (Paris: Gauthier-Villars, 1904–1916, 7 vols.)

was never completed, but included some revisions, especially historical footnotes that are often very useful. See also items 2283, 2896.

6. Eneström, G. "Bio-bibliographie der 1881–1900 verstorbenen Mathematiker". *Bibliotheca Mathematica* 2 (1901), 326–350.

List of obituary notices of some three hundred mathematicians. Many are not recorded in Poggendorff, items 16, 17, nor in Kenneth May's *Bibliography*, item 14.

7. Fang, J. *A Guide to the Literature of Mathematics Today.* Hauppauge, N.Y.: Paideia, 1972.

Provides a guide to international congresses, mathematical societies, a comparison of major topics in mathematics in 1900 versus 1970, and lists of major series (colloquiums, memoirs, proceedings, translations). A section is devoted to collected works.

8. Gillispie, Charles Coulston, editor in chief. *Dictionary of Scientific Biography.* New York: Scribner's, 1970–1990. 18 vols.

Probably the single most important reference work in the history of science today, with signed bio-bibliographical articles on non-living scientists who were deemed to have made an "identifiable difference to the profession or community of knowledge." Volume 16 contains a name and subject index and a listing of scientists by field. The editor describes his work with the publisher Charles Scribner, "most of whose associates were mathematicians and exact scientists", in "Eloge: Charles Scribner, Jr., 12 July 1921–11 November 1995," *Isis* 88 (1997), 302–303.

9. Gottwald, Siegfried, Hans Joachim Ilgauds, and Karl-Heinz Schlote, eds. *Lexikon bedeutender Mathematiker.* Thun: H. Deutsch, 1990.

The best concise biographical dictionary of mathematicians.

10. Grattan-Guinness, Ivor. ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* London; New York: Routledge, 1994. 2 vols., xiii, 1806 pp.

The single best starting point for the beginner in history of mathematics as well as a resource for the expert. The 180 articles by 135 contributors are grouped under the following headings, each section having its own introduction: 1. Ancient and non-Western traditions, 2. The Western Middle Ages and the Renaissance, 3. Calculus and mathematical analysis, 4. Functions, series and methods in analysis, 5. Logic, set theories, and the foundations of mathematics, 6. Algebras and number theory, 7. Geometries and topology, 8. Mechanics and mechanical engineering, 9. Physics and mathematical physics, electrical engineering, 10. Probability and statistics, and the social sciences, 11. Higher education and institutions, 12. Mathematics and culture, 13. Reference and information. See also the editor's 896 which is keyed in many places to the *Companion Encylcopedia.*

11. *International Catalogue of Scientific Literature*. Section A: *Mathematics*; Section B: *Mechanics*. London: Harrison, 1902–1918. Reprinted New York: Johnson Reprint Corp., 1968.

Grew out of the Royal Society's *Catalogue of Scientific Papers*, and was intended to cover literature after 1900. The 28 volumes for sections A and B cover 1901 to 1914. Each volume contains schedules and indexes in four languages, bibliography arranged by author, and bibliography arranged by subject (including history and biography).

12. *Isis Cumulative Bibliography: A Bibliography of the History of Science Formed from Isis Critical Bibliographies 1–90, 1913–1965.* London: Mansell, 1971–1976. Supplementary volumes published through 1990 bring the coverage through 1985.

Cumulations of the annual bibliographies edited by Neu, John published as part of the journal *Isis*. The volumes are indexed by individuals and institutions as well as subject. The bibliographies are available to members of the History of Science Society through the Internet as part of the History of Science and Technology database maintained by the Research Libraries Group, Inc.

13. Jayawardene, S. A. "Mathematical Sciences". In *Information Sources in the History of Science and Medicine*. Edited by P. Corsi and P. Weindling. Boston, London: Butterworths, 1983.

Contains bibliographic essays on various topics in the history of science and medicine. The chapter on mathematics is devoted to an extensive essay on mathematics since the Renaissance.

14. May, Kenneth O. *Bibliography and Research Manual of the History of Mathematics*. Toronto: University of Toronto Press, 1973.

Aims to include all secondary literature in the field of the history of mathematics for the period 1868–1965. Arrangement is alphabetical under the following sections: biography, mathematical topics, epi-mathematical topics (e.g., the abacus, women, and Zeno's paradoxes), historical classifications (time periods, countries, cities, organizations), and information retrieval (bibliographies, historiography, information systems, libraries, manuscripts, museums, monuments, exhibits). This is an essential starting point for any beginning historian of mathematics who wishes a speedy introduction to the relevant literature on a given topic or individual.

The bibliographies and abstracting journals incorporated by May are noted as such in the present bibliography. For Oriental studies May should be supplemented by other works such as Suter, item 1239, Sezgin, item 1091, and Pingree, item 1459. For Chinese mathematics, there is Joseph Needham, *Science and Civilization in China*, Vol. 3 (Cambridge University Press, 1959). May is reviewed in *Historia Mathematica* 1 (1974), 192–194.

See also item 1018.

15. Müller, Felix. *Führer durch die mathematische Literatur, mit besonderer Berücksichtigung der historisch wichtigen Schriften.* (Abhandlungen zur Geschichte der mathematischen Wissenschaften 27.) Leipzig: Teubner, 1909. Reprinted Nendeln, Liechtenstein: Kraus Reprint, 1979.

Provides annotations in the form of running commentary on the literature of mathematics and its history. Classified by subject with indexes to subjects and names. Still useful for works in pure mathematics before 1868 and a guide to the historical literature before 1909.

16. Poggendorff, Johann Christian, ed. *Biographisch-literarisches Handwörterbuch zur Geschichte der exakten Naturwissenscahften.* Leipzig: J. A. Barth, 1863–1919?; Berlin: Verlag Chemie, 1925–1940. 6 vols. in 11.

17. Poggendorff, Johann Christian, ed. *Biographisch-literarisches Handwörterbuch der exakten Naturwissenschaften, unter Mitwirkung der Akademien der Wissenschaften zu Berlin, Göttingen, Heidelberg, München, und Wien.* Berlin: Akademie Verlag, 1955–.

Contains short biographical information followed by a list of books and articles by and about each scientist. Entries were updated from volume to volume and thus all chronological divisions may need to be consulted for complete information on a given personality. Some entries have been provided by the scientists themselves. Though weak on pre-1800 scientists, it is indispensable for the nineteenth century. Historians of science are included from volume 6 on. See also item 2279.

18. Read, Cecil B., and James K. Bidwell. "Selected Articles Dealing with the History of Elementary Mathematics. (Periodical Articles Dealing with the History of Advanced Mathematics)". *School Science and Mathematics* 76 (1976), 477–483, 581–598, 687–703.

Arranges some 2,000 articles under 28 subject headings, with coverage beginning in 1934.

19. Riccardi, Pietro. *Biblioteca matematica italiana dalla origine della stampa ai primi anni del secolo XIX.* Modena: Societa Tipografica, 1873–1928. Reprinted Milan: Goerlich, 1952.

A bibliography of some 10,000 books on mathematics and its applications by Italian authors who lived before 1811. Access is by author and chronological under 262 subject headings. List of about 800 works cited in the annotations.

20. Royal Society of London. *Catalogue of Scientific Papers, 1800–1900.* London: C. J. Clay, 1867–1902; Cambridge: University Press, 1914–1925. 19 vols. *Subject Index (Pure Mathematics, Mechanics,*

Physics). Cambridge: University Press, 1908–1914. 3 vols. in 4. Reprinted New York: Johnson Reprint, 1965.

Intended to contain every scientific memoir (including history of science) which appeared in transactions and proceedings of societies and in journals. The index volumes for pure mathematics and mechanics contain separate sections for historical material and serve to supplement May's *Bibliography*, item 14. See also item 2280.

21. Russo, F. *Histoire des sciences et des techniques. Bibliographie*. Paris: Hermann, 1954. Supplement, 1955.

An essential reference book for the historian of science, whatever his speciality. While Sarton's guides (items 12 and 42) do not deal for the most part with primary sources, Russo devotes about half of his book to them. The volume opens with a brief survey of materials devoted to societies and institutes for the history of science, congresses, and biographies of historians of science, then discusses libraries, archives, museums, periodicals, general works, works by time period, and works for the various sciences. Nearly ten pages are devoted to mathematics. Well indexed.

PERIODICALS

The *Isis Guide to the History of Science 1992* (published by the History of Science Society) includes a listing of 140 journals that relate to the history of science, many of them including the history of mathematics. The *Archive for History of Exact Sciences* (Berlin: Springer Verlag, 1960–) publishes a substantial number of history of mathematics papers. Also of value is *Osiris; Studies on the History and Philosophy of Science, and on the History of Learning and Culture* (Chicago: The University of Chicago Press, 1936–). The only journals devoted exclusively to the history of mathematics are *Historia Mathematica* (New York: Academic Press, 1974–), *Ganita Bharati, Bulletin of the Indian Society for History of Mathematics*, edited by R. C. Gupta (Ranchi, India, 1979–), *Bollettino di Storia della Scienze Matematiche* (Florence: Istituto di Matematica, 1981–), *Mathesis* (México: Departamento de Matemáticas, Facultad de Ciencias, Universidad Nacional Autónoma de México, 1985–), and *Revue d'Histoire des Mathématiques* (Marseille: Soc. Math. France, 1995–).

Useful journals which have ceased publication are listed below:

22. *Abhandlungen zur Geschichte der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen.* 1877–1913. 30 vols. Volumes 1–10 issues as supplement to *Zeitschrift für Mathematik und Physik. Leipzig, 1877–1913.*

23. *Archiv für die Geschichte der Naturwissenschaften und der Technik.* Leipzig, 1900–1931. Continued as *Archiv für Geschichte der Mathematik*, and then as *Quellen und Studien zur Geschichte der Naturwissenschaften und der Medicin.* See item 27.

24. *Bibliotheca Mathematica* 1 (1884)– 3 (1886); Neue Folge, 1 (1887)– 13 (1899); Dritte Folge, 1 (1900)– 14 (1913–1914). Stockholm, 1887–1899; Leipzig, 1900–1914.

    The first series indexed newly published books, articles, and papers in the area of pure mathematics, giving occasional brief historical notes. The second series emphasized the history of mathematics exclusively. The third series, in addition to listing newly published works, included substantial historical articles treating subjects from antiquity to the most current mathematical topics.

25. *Bollettino di Bibliografia e Storia delle Scienze Matematiche.* Edited by Loria, G.. Turin, 1898–1919.

    Places great emphasis on book reviews and announcements covering literature in all

26. *Bullettino di Bibliografia e di Storia delle Scienze Matematiche e Fisiche.* Rome: Tipografia delle Scienze Matematiche e Fisiche, 1868–1887.

    Volume 20 contains an index by author for the 20 volumes of the *Bulletino.* Authors include Boncompagni, M. Cantor, Favaro, Genocchi, Sédillot, Steinschneider. A list of edited documents also appears, from Abū-l-Wafā' and the Arabic text of his *Kitab al Mobarek* to a note by Zucchetti in the Gonzaga archives in Mantua.

27. *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik*. Berlin: J. Springer, 1930–1936. 4 vols. Series A is devoted to sources. Title varies slightly. See item 23.

28. *Rete: Strukturgeschichte der Naturwissenschaften*. Hildesheim, 1971–1975.

29. *Scripta Mathematica: A Quarterly Journal Devoted to the Philosophy, History, and Expository Treatment of Mathematics*. New York, 1932–1973.

30. *Zeitschrift für Mathematik und Physik. Historisch-literarische Abtheilung*. Leipzig, 1865–1900.

ABSTRACTING JOURNALS

31. *Bulletin signalétique. 522. Histoire des sciences et des techniques.* Paris: Centre de Documentation Sciences Humaines, 1962–.

Covers a wide range of journals to produce a bibliography of articles and book reviews, arranged by subject and period and briefly annotated. There are annual cumulative subject and author indexes.

32. *Historia Mathematica.* New York: Academic Press, 1974–.

Articles, books, and other media, in all languages, in the field of the history of mathematics are abstracted in each quarterly issue with an index by author or main entry in the last issue of each year. Author and subject indexes to the abstracts were prepared by Albert C. Lewis for the first thirteen volumes; they appear in vols. 13(4) and 14(1) respectively.

33. *Jahrbuch über die Fortschritte der Mathematik.* 1868–1943. Berlin: de Gruyter, 1871–1943. 68 vols.

Classified annotated bibliography of articles in contemporaneous journals with a section for history and philosophy. Indexed by author. See item 2289 for further information and availability in electronic form.

34. *Mathematical Reviews.* Providence, R.I.: American Mathematical Society, 1940–.

Abstracts and reviews books and articles in nearly 1,200 journals. A special effort is made to cover material published in Russian. Reviews, written by experts in each field, are critical in nature. *Mathematical Reviews* appears monthly and includes a separate section for history and biography. Historical items for the years 1940–1966 are included in May's *Bibliography*, item 14. The publisher also provides the service as an electronic database accessible to subscribers over the Internet.

35. *Referativny Zhurnal: Matematika.* Moscow: Akademiia Nauk SSSR, 1953–.

All reviews are in Russian. The scope is comparable to *Mathematical Reviews*, item 34, and the *Zentralblatt*, item 37, but with greater emphasis given to pedagogy.

36. *Revue semestrielle des publications mathématiques.* 1893–1932.

Half-yearly index of journal articles. The five-year cumulative indexes have a history section and an index of biographies. Historical items are included in May's *Bibliography*, item 14.

37. *Zentralblatt für Mathematik und ihre Grenzgebiete (reine und angewandte Mathematik, theoretische Physik, Astrophysik, Geophysik).* Berlin: Springer, 1931–.

Covers a range of mathematical literature similar to *Mathematical Reviews*, item 34. In early years it relied more upon author abstracts. The

European Mathematical Society provides the *Zentralblatt* in electronic database form accessible to subscribers over the World Wide Web.

HANDBOOKS, INDEXES AND DIRECTORIES

38. Jayawardene, S. A. *Reference Books for the Historian of Science: A Handlist*. London: Science Museum Library, 1982.

Consists of some 1,000 titles arranged in 44 chapters. There are detailed subject and author/title indexes. Sections I, 3; II, 4; VI, 1, b; VI, 3, b; and VII, 2 are specifically devoted to mathematics. Special sections deal with libraries, archives, manuscripts, theses, and dissertations.

39. Jayawardene, S. A., and Jennifer Lawes. "Biographical Notices of Historians of Science: A Checklist". *Annals of Science* 36 (1979), 315–394.

Includes 128 historians of mathematics among the 800 historians of science and 3,000 notices. Bibliographies and portraits are indicated.

40. Loria, Gino. *Guida allo studio della storia delle matematiche; generalità, didattica, bibliografia*. 2nd ed. Milan: Hoepli, 1946.

A series of bibliographical essays in which some 1,600 titles are enumerated and commented on. In spite of superfluous detail in some chapters, and many errors in the index, this first bibliographical handbook for the historian of mathematics is still informative. Personal names are indexed, but not subjects.

41. Andersen, Kirsti, and Mette Dybdahl, eds. *World Directory of Historians of Mathematics*. Third edition. Aarhus, Denmark: International Commission on the History of Mathematics, 1995.

A listing with addresses of historians of mathematics indexed by country of residence and subject interests.

42. Sarton, George. *The Study of the History of Mathematics*. Cambridge, Mass.: Harvard University Press, 1937. Reprinted New York: Dover, 1957.

Consists of a text on the meaning of the history of mathematics, and an annotated bibliography (25 pages) intended for beginners. Although the work is outdated in many respects, Sarton's annotations are still of interest. As a companion volume should be mentioned Sarton's *A Guide to the History of Science (Horus)* (Waltham, Mass.: Chronica Botanica Co., 1952), which includes a chapter on mathematics. No single guide since *Horus* has covered all the topics treated in it, and many of these are of general interest to historians of mathematics.

WORLD WIDE WEB

The World Wide Web contains a vast and diverse array of material on various aspects of history of mathematics, and is potentially one of the most powerful resources in the subject commonly available. Sites cover from a broad spectrum from interactive texts and museum catalogues, through to high school student projects and a wide of reference sources. However, since anyone, anywhere, can place material on the Web, and since the contents of a site can change at any time without notice, it is essential to maintain a critical awareness when viewing sites. In particular, the location of a site is no guarantee of reliability. It is therefore important to develop a strategy for judging the quality of the information found. Such a strategy should include assessing the authority of the author of the site as well as the accuracy and currency of the information. Many contain links to other sites, for which they bear no responsibility, and thus whose quality needs to be assessed independently.

The following is a categorization of Web sites relating to the history of mathematics. The categorization, which is by subject matter, has been chosen in order to give a sense of the type of areas the Web now covers rather than to fit in with a rigid predetermined scheme. Each category contains a number of sites which have been selected because, at the time of writing, they represent good examples of their type. The list of sites is obviously not intended to be exhaustive (nor indeed is the characterization) but rather its aim is to provide an indication of the type of material currently available. Since the Web is a dynamic object and the lifetime of a site unpredictable, especially in the case of a site created and maintained by an individual, there is no absolute guarantee that the standard of any particular site will remain high or up to date or that it will remain accessible indefinitely.

Some of the special features noted in the annotations, such as high-quality images and large texts can be slow to download; some sites are interactive and require a specially enabled browser.

General

These are large sites that have several pages ranging across a variety of topics.

43. The MacTutor History of Mathematics Archive (http://www-history.mcs.st-and.ac.uk/history/) was created and is maintained by John O'Connor and Edmund Robertson of St Andrews University, and contains the most comprehensive collection of biographies of mathematicians currently available. The collection of more than 1,000 biographies is illustrated, referenced, and indexed both alphabetically and chronologically. There are birthplace maps, as well as a separate index of female mathematicians. It also contains a variety of resources on the developments of various branches of mathematics, including an interactive

(Java) famous curves index, and pages on mathematical societies, medals, and honors. It is an extremely rich and extensive site with some excellent pages although the quality is not always consistent. In particular, some of the biographies should be viewed with care.

44. David Joyce's History of Mathematics Home Page (http://aleph0.clarku.edu/~djoyce/mathhist/mathhist.html) is the starting point to a wealth of resources provided by David Joyce of Clark University. There are pages on regional mathematics, mathematical topics, books, journals, bibliography, history of mathematics texts etc, as well as an excellent list of clearly categorized Web resources, a detailed chronology, and timelines.

45. The Mathematical Museum - History Wing (http://www.math-net.de/links/show?collection=math.museum) is part of the Math-Net Links to the Mathematical World which has been developed by the Konrad-Zuse-Zentrum fur Informationstechnik, Berlin (ZIB). It contains links to exhibitions, hyperbooks, information systems, museums and pages of interest for the history of mathematics and associated fields. There are sections on history of mathematics, history of computing and communication, and related history information. It is well annotated and includes some sample illustrations.

46. The Math Forum Internet Resource Collection (http://forum.swarthmore.edu/) is part of the Math Forum, an on-line mathematics education community centre, hosted by Swarthmore College, and provides an extensive list of annotated links to other sites. The sites are ordered alphabetically and the collection can be viewed in outline or annotated form. There is a well designed search engine which allows for a variety of searches, i.e. keywords, categories and dates.

47. Trinity College, Dublin, History of Mathematics archive (http://www.maths.tcd.ie/pub/HistMath/HistMath.html) is the work of David Wilkins, contains mathematical papers and other material relating to Hamilton, Riemann, Berkeley, Boole, Cantor and Newton. It also includes biographies of some seventeenth and eighteenth century mathematicians taken from *A Short Account of the History of Mathematics* (4th edition, 1908) by Ball, W. W. Rouse, and a directory of Web sites.

48. WWW Virtual Library. History of Science, Technology and Medicine (http://www.asap.unimelb.edu.au/hstm/) is part of the WWW Virtual Library Project. It was developed and is maintained by Tim Sherratt, formerly of the Australian Archives Project. It is the gateway into a wide range of resources covering the history of many scientific fields including mathematics. A particular feature of the site is its rating system that, with given criteria, evaluates the depth, content and design of each site listed.

Biography

There is plenty of material on the Web concerned with lives of mathematicians. It comes in a wide variety of guises, much of it excellent, and, on the whole, the Web is a very good place to start looking for biographical material. General sites include compendiums of biography as well as sites devoted to particular groups, e.g. mathematicians of a particular period and/or place. There are also many sites devoted to individuals. The latter generally contain a broad spectrum of material about the individual with links to other relevant sites. Many of the sites are well illustrated, although some of the early 'portraits' should be treated with circumspection.

General Biography

49. A Bibliography of Collected Works of Mathematicians (`http://www.math.cornell.edu/~library/collectedwks.html`) is an extensive bibliography compiled and maintained by Steven Rockey, the mathematical librarian at Cornell University. Though this bibliography is also the basis for the Collected Works section of the present *Selective Bibliography*, the World Wide Web version is continually augmented.

50. Biographies of Women Mathematicians (`http://www.agnesscott.edu/lriddle/women/women.htm`) is part of an ongoing project by students in mathematics classes at Agnes Scott College, Atlanta, to illustrate the achievements of women in mathematics. It includes biographical essays or comments on many women mathematicians and some photographs. The material is indexed both alphabetically and chronologically. The site also includes a page on prizes and honors for women mathematicians, and a list of other resources. It is maintained by Larry Riddle.

51. Portraits of Statisticians (`http://www.york.ac.uk/depts/maths/histstat/people/`) is a collection of portraits of approximately two hundred statisticians, including several mathematicians who dabbled in statistical work, ranging from the 15th century to the present day, compiled by Peter Lee of York University. There is no text but the sources, together with some biographical references, are included.

52. Richard Westfall's Archive of the Scientific Community in the 16th and 17th Centuries (`http://es.rice.edu/ES/humsoc/Galileo/Catalog/catalog.html`) contains concise biographical details of about 630 members of the scientific community in the 16th and 17th centuries, of which about 170 are mathematicians. The individuals are systematically described by ten categories (which are fully explained) using twenty searchable fields. The data, which is presented formally, is well organized and includes details of the sources consulted. (It is not obvious on this site which biographies are of most interest to historians of mathematics: a list of the mathematicians can be found through a link on the St Andrew's site.)

53. St Andrews Archive (http://www-history.mcs.st-and.ac.uk/history/BiogIndex.html) See the entry under 'The MacTutor History of Mathematics Archive' in the General section above.

Individual Biography

54. Archimedes (http://www.mcs.drexel.edu/~crorres/Archimedes/contents.html) is an extremely rich collection of Archimedean miscellanea produced by Chris Rorres of Drexel University, Philadelphia, including a pages on different aspects of Archimedes' mathematics, books on Archimedes, information on Syracuse, and links to other related sites, e.g. a bibliography of Archimedean literature.

55. George Green (http://www.nottingham.ac.uk/~ppzwww/green/) is an attractively illustrated introduction to George Green's life and work produced by the Physics Department at Nottingham University. The site includes a short biography, a list of Green's publications, a list of further references, as well as sources of archival material. There is also a link to Green's Mill and Science Centre.

56. Hypatia of Alexandria (http://poly.polyamory.org/~howard/Hypatia/) is an extensive and partially annotated list of Web resources connected with Hypatia collected by Howard Landman. The internal links include a long list of published books and articles which contain information on Hypatia, as well as transcriptions from 18th and 20th century texts.

58. Newtonia (http://www.newton.org.uk) contains a wide-ranging collection of material about Isaac Newton, as well as information about places and people significant to him. It was created by of Andrew McNab of Manchester University and there are good links to other Newton resources.

59. Henri Poincaré (http://uhp.u-nancy.fr/~riess/poincare/index.html) is an extensive site devoted to Poincaré maintained by the University of Nancy. It includes a short biography, a chronology, photographs, links to the Poincaré archives and to other related sites.

60. The Alan Turing Home Page (http://www.turing.org.uk/turing/) is a large and well-structured site on Turing's life and work maintained by Andrew Hodges. It includes material on the history of the computer as well as links to other related sites.

Regional

Although there are several sites on regional and ancient mathematics, many of them are the work of students and relatively few are the result of scholarship, although some of the general sites, notably David Joyce's site and the St Andrews' site, listed in the General section above, do include good regional pages.

61. Mesopotamian Mathematics (http://it.stlawu.edu/~dmelvill/mesomath/index.html) contains a considerable amount of interesting and historically accurate material, collected and written by Duncan Melville of St Lawrence University for his undergraduate history course, with an extensive annotated bibliography by Eleanor Robson of the Oriental Institute, Oxford.

62. Mathematicians of the African Diaspora (http://www.math.buffalo.edu/mad/mad0.html) was created and is maintained by Scott Williams of the State University of New York at Buffalo, to exhibit the accomplishments of the people of Africa and the African Diaspora within the mathematical sciences. Among the history pages are pages on the mathematics of Ancient Egypt, Pre-Colonial Nigeria, and Swaziland (the Lemombo Bone). There are good links to other related sites.

Museums

It is now fairly standard practice for museums to use the Web to promote their current exhibitions as well as their permanent collections, and overall the quality of museum sites is extremely high. Some museums put their exhibition catalogues on-line, and these provide a very useful resource.

63. IMSS - The Institute and Museum of the History of Science, Florence: Galileo Room (http://galileo.imss.firenze.it/museo/b/egalilg.html) is a hypermedia catalogue of the Museum's Galileo room. It contains a biography of Galileo as well as exhibits devoted to his contributions to mechanics, astronomy, the microscope, thermometry and magnetism. There are also short biographies of other individuals connected to Galileo. This is an extremely well illustrated site.

64. Library of Congress Vatican Exhibit Mathematics Room (http://lcweb.loc.gov/exhibits/vatican/math.html) is a hypertext site containing annotated Greek and Latin manuscripts of mathematics and astronomy, with very high quality images including a 9th century version of Euclid's Elements showing the Pythagorean Theorem and a 13th and 15th century versions of Archimedes' Works.

65. The Museum of the History of Science, Oxford (http://www.mhs.ox.ac.uk/) contains three on-line exhibitions which are of particular interest for the history of mathematics: *The Measurers: A Flemish Image of Mathematics in the Sixteenth Century* ; *The Geometry of War 1500-1750* and *The Noble Dane: Images of Tycho Brahe*.

Virtual Exhibitions

These are sites which have been specially developed for the Web from a variety of sources. They make use of a variety of devices, some of which are only available to those with sufficiently enhanced browsers, and tend to be very image intensive. It is not always necessary to enable all the tools in order to get a good sense of the potential of the sites.

66. The Art of Renaissance Science: Galileo and Perspective (http://www.crs4.it/Ars/arshtml/arstitle.html) is a beautifully illustrated discussion by J. W. Dauben of the interconnections between art and science in the Renaissance, in particular the development of perspective, and how these connections relate to the role of Galileo in the Scientific Revolution. As well as excellent images, the pages also contain animations, video clips and music.

67. Galileo Project at Rice University (http://es.rice.edu/ES/humsoc/Galileo/) is a superb hypertext source of information on the life and work of Galileo and the science of his time. This is an extremely rich and well designed site with very high quality images, e.g. the "Instrument Closet," which contains text and images about the instruments used by Galileo to perform his experiments.

Texts

Texts on-line come in two forms: straightforward copies of original texts, particularly useful if the text in question is otherwise difficult to obtain, or copies which have been annotated or translated in order to increase accessibility.

68. Edwin Abbott: 'Flatland' (http://attila.stevens-tech.edu/math_history/authors/Abbott/flat10.txt) contains the full text of *Flatland* in plain text. Although there are no illustrations, the length of the text means that it takes time to download.

69. Euclid's Elements (http://aleph0.clarku.edu/~djoyce/java/elements/toc.html) contains the full text interactive version of Euclid's Elements with historical and mathematical comments produced by David Joyce. With a Java enabled browser it is possible to dynamically change the diagrams. A remarkable site which makes the Elements accessible in a completely new way.

70. The History of Hypatia (http://poly.polyamory.org/~howard/Hypatia/) is a partial transcription of a very rare 18th century text, the full title of which is *The History Of Hypatia, A most Impudent School-Mistress of Alexandria: Murder'd and torn to Pieces by the Populace, In Defence of Saint Cyril and the Alexandrian Clergy. From the Aspersions of Mr. Toland*.

71. The Perseus Project, Tufts University. (http://www.perseus.tufts.edu/Texts/chunk_TOC.html) contains translations (and originals) of many works of ancient Greek authors, including the works of Aristotle, and Euclid's Elements with Heath's commentary.

72. The Mathematical Papers of Bernhard Riemann (http://www.maths.tcd.ie/pub/HistMath/People/Riemann/Papers.html) contains papers by Riemann, extracts from Riemann's correspondence and further material from Riemann's Nachlass, collected together by David Wilkins.

Scholarly Articles

Several authors have incorporated articles into their own sites which may or may not have been published elsewhere.

73. The art of algebra from Al-Khwarizmi to Viéte: A study in the natural selection of ideas (`http://www.lib.virginia.edu/science/parshall/algebra.html`) is an article by Karen Parshall of the University of Virginia, that first appeared in the journal *History of Science*.

74. A Brief History of Algebra and Computing: An Eclectic Oxonian View (`http://www.museums.reading.ac.uk/vmoc/algebra/`) is an article by Jonathan Bowen of Reading University, that was first published in the IMA Bulletin.

75. Greek Diagrams: their Use and their Meaning (`http://www.mrc-cbu.cam.ac.uk/projects/twd/contributions/netz-paper.html`) is an article by Reviel Netz of Cambridge University. It is based on talk given at the Third International Conference for the History of Greek Mathematics.

76. The Mathematics of Fermat's Last Theorem (`http://www.best.com/%7Ecgd/home/flt/flt01.htm`) is a hypertext site created by Charles Daney to provide an overview of some of the mathematics that has been developed over the years to try to solve the problem (directly or indirectly) and some other mathematics that has been found to be relevant. The emphasis is on the overall picture rather than technical details.

Education

A variety of sites provide resources for teachers and others with interest in the use or incorporation of historical material in mathematical education.

79. BSHM Education Abstracts (`http://www.dcs.warwick.ac.uk/bshm/abs.html`) See 'BSHM Abstracts' under Resources.

80. History of Mathematics with Original Sources (`http://www.nsm.iup.edu/ma/gsstoudt/history/ma350/sources_home.html`) contains a collection of materials for using original sources in a history of mathematics class. The site, which is the work of Gary Stoudt of Indiana University of Pennsylvania, contains a reading list, and a collection of discussion questions and homework problems, together with images of famous works.

Philosophy of Mathematics

The history of the philosophy of mathematics appears on the Web in a variety of ways. For example, there are sites devoted to philosophy in general which include material on the philosophy of mathematics; there are sites devoted to individual philosophers of mathematics; and there are sites which contain the texts (in translation if appropriate) of philosophers of mathematics.

81. The Bertrand Russell Archives at McMaster University (http://www.mcmaster.ca/russdocs/russell.htm) is an extensive site containing an enormous array of Russell resources including scanned images of Russell documents, correspondence records, a guide to Russell's writings, and many other resources.

82. The Internet Encyclopaedia of Philosophy (http://www.utm.edu/research/iep/) is a general site on philosophy which includes articles on the philosophy of, amongst others, Aristotle, Descartes, and Poincaré.

Computing

History of computing is well represented on the Web, both in terms of individuals and institutions, and in terms of calculating machines/devices, and computers.

83. Alan Turing (http://www.turing.org.uk/turing/) See entry under Individual Biography' above.

84. Bletchley Park (http://www.cranfield.ac.uk/ccc/bpark/) is a well-illustrated site giving detailed information about Bletchley Park—activities past and present—and a good collection of links to related sites.

85. Charles Babbage's Analytical Engine (http://www.fourmilab.ch/babbage/contents.html) contains texts of historical documents, including Menabrea's description of the Engine translated by Ada Lovelace, and a detailed description of an Analytical Engine emulator which runs as a Java applet.

86. The Virtual Museum of Computing (http://www.museums.reading.ac.uk/vmoc/) is a site developed and maintained by Jonathan Bowen of Reading University. It consists entirely of an extensive collection of links to sites connected with the history of computing and computer-based exhibits. The site is divided into galleries covering a variety of topics such as general historical information, on-line exhibits etc.

Resources

The ability of the Web to provide continually updated information, particularly textual information, is an extremely valuable feature of the medium. Standard resources, such as bibliographies, can be kept up to date, while more specialised resources can be immediately revised should new information comes to light. And such new information may come from any other user of the Web, thus providing the opportunity for, in effect, international collaborative projects: a true network of scholars.

87. BSHM Abstracts (http://www.dcs.warwick.ac.uk/bshm/abs.html) contains brief abstracts, sorted alphabetically by author, of history of mathematics papers published in journals and books, produced and regularly updated by John Fauvel of the Open University. There is a

separate education section covering abstracts of papers on the uses of history of mathematics in education, history of mathematics courses, and the history of mathematics education.

88. Earliest Uses of Various Mathematical Symbols (http://members.aol.com/jeff570/mathsym.html) Earliest Known Uses of Some of the Words of Mathematics (http://members.aol.com/jeff570/mathword.html) are the product of multiple contributors. They are of high quality and provide an excellent resource. They are maintained by Jeff Miller of Gulf High School, Florida and contributions are welcomed.

89. Texts on the History of Mathematics (http://aleph0.clarku.edu/~djoyce/mathhist/textbooks.html) is a list of texts including textbooks and similar general references compiled by David Joyce.

Journals

Increasingly journals are being made available on the Web. Sometimes this is on open access, sometimes you need to make arrangements to pay, but there are generally indexes and quite full information about the journal.

90. Annals of Science (http://www.journals.tandf.co.uk/) contains information about the journal and links to journals of related interest.

91. Archive for History of Exact Sciences (http://link.springer.de/link/service/journals/00407/index.htm) contains information about the journal and tables of contents for recent issues.

92. Historia Mathematica (http://www.chass.utoronto.ca/hm/) contains information about the journal, tables of contents for all volumes, a list of journals in related fields, and links to other sites.

93. Isis (http://www.journals.uchicago.edu/Isis/) contains information about the journal and tables of contents for volumes from 1995.

94. Science in Context (http://www.cup.cam.ac.uk/scripts/webjrn1.asp?Mnemonic=sic) contains information about the journal and a list of recent articles.

Societies

Most academic disciplines have societies which exist to help the promotion of their subject at a variety of levels. The Web now provides a very convenient way to find out what such Societies offer the public, how much it costs to join (if applicable), as well as supplying a means of obtaining an application form.

95. The British Society for the History of Mathematics (http://www.dcs.warwick.ac.uk/bshm/) includes membership details, BSHM abstracts, an archive containing a list of talks given to the Society, and a page of links to other sites.

96. The British Society for the History of Science (http://www.man.ac.uk/Science_Engineering/CHSTM/bshs/) includes membership details, information about meetings, a list of journals, and a page of links to other sites.

97. The Canadian Society for the History and Philosophy of Mathematics (http://www.adelphi.edu/~cshpm/) includes membership details, free access to the *History and Pedagogy of Mathematics Newsletter*, and a page of links to other sites.

98. The Deutsche Mathematiker-Vereinigung (DMV) subgroup for history of mathematics (http://sun-10.math-inf.uni-greifswald.de/geschichte) contains news about the congresses of the subgroup, and bibliographies from journals of the GDR. (It is in German.)

99. The Royal Society (http://www.royalsoc.ac.uk/) is an extensive site containing information about the Royal Society's activities, publications, library etc.

II. SOURCE MATERIALS

SOURCE BOOKS

100. Bellman, R. *A Collection of Modern Mathematical Classics.* New York: Dover, 1961.

Photographically reproduces thirteen classical papers in eighteenth- and nineteenth-century analysis ("the field we have arbitrarily selected for this initial collection"—no more were published) by each of the following: C. Hermite; G. H. Hardy and J. E. Littlewood; P. L. Chebyshev; L. Fejér; I. Fredholm; L. Fuchs; A. Hurwitz; H. Weyl; B. van der Pol; G. D. Birkhoff; G. D. Birkhoff and O. D. Kellogg; J. von Neumann; D. Hilbert. Each paper is preceded by a short one- or two-page introduction.

101. Birkhoff, Garrett, ed. with the assistance of Uta Merzbach. *A Source Book in Classical Analysis.* Cambridge, Mass.: Harvard University Press, 1973.

Presents English translations, with brief historical introductions and explanatory footnotes, of nineteenth-century treatises on analysis. The selection is of "some of the most influential writings of the greatest mathematicians of a period in which, truly, (classical) analysis dominated mathematics." A two-page bibliography and two-page index are appended. See also item 2282.

102. Midonick, Henrietta. *The Treasury of Mathematics. A Collection of Source Material in Mathematics...with Introductory Biographical and Historical Sketches.* London and New York, 1965. Reprinted Harmondsworth, England: Penguin Books, 1968.

Translates into English, some for the first time, excerpts from published works. Covers antiquity (including Eastern) up to C. S. Peirce, G. Cantor, and G. Frege.

103. Moritz, Robert E. *On Mathematics and Mathematicians.* New York: Dover, 1958, vii +410 pp. Originally published as *Memorabilia Mathematica or The Philomath's Quotation Book.* New York: Macmillan, 1914.

Over 1,000 quotations arranged by subject (e.g., the value of mathematics, mathematics and logic, algebra, paradoxes and curiosities) in English translation with index.

104. Newman, James R. *The World of Mathematics. A Small Library of the Literature of Mathematics from A'h-mosé the Scribe to Albert Einstein, Presented with Commentaries and Notes.* New York: Simon and

Schuster, 1956. Reprinted Redmond, Wash.: Tempus Books, 1988. 4 vols.

One of the broadest anthologies in scope. Vol. 1, Part II, is devoted to history and biography from the Rhind Papyrus to B. Russell and A. N. Whitehead, though there are a number of historical articles elsewhere. General index in Vol. 4.

105. Smith, David Eugene, ed. *A Source Book in Mathematics*. 1st ed. New York: McGraw-Hill, 1929. Reprinted New York: Dover, 1959. 2 vols.

Excerpts, generally five or six pages in length, from Renaissance and post-Renaissance treatises. All are translated into English and many of the translators are well-known modern specialists in the relevant mathematical subject (e.g., "Gauss on the Third Proof of the Law of Quadratic Reciprocity" is translated from the Latin by D. H. Lehmer). Short introductions and some modern explanations (carefully put in square-bracketed footnotes) are given. See also items 2284, 3493.

106. Speiser, Andreas. *Klassische Stücke der Mathematik*. Zurich, Leipzig: Füssli, 1925.

German translations of twenty-five selections, generally expositions about mathematics, from Euclid to Einstein. Short pieces are included from Dante, da Vinci, Kepler, Goethe, Rousseau, Euler, and Sylvester.

107. Struik, Dirk J. *A Source Book in Mathematics: 1200–1800.* Cambridge, Mass.: Harvard University Press, 1969. Reprinted Princeton, N.J.: Princeton University Press, 1986, xiv + 427 pp.

Selections in English translation from works in the Latin world (i.e., none from Arabic or Oriental authors unless a much used Latin translation was available). Confined to pure mathematics and those fields of applied mathematics having a direct bearing on the development of pure mathematics. Extensive historical introductions and commentaries. Arranged by subject: arithmetic; algebra; geometry; analysis before Newton and Leibniz; Newton, Leibniz, and their schools.

108. Wieleitner, Henrich. *Mathematische Quellenbücher*. Berlin: Verlag Salle, 1927–1928.

Issued in four parts as volumes 3, 11, 19, and 24 in a larger series devoted to science. Excerpts from the literature are given under the headings: numerical calculations and algebra (Roman numerals and Egyptian fractions to Descartes and Euler); geometry and trigonometry (Hippocrates, Pappos, and Euclid to De Moivre); analytic and synthetic geometry; and infinitesimal calculus (Axiom of Archimedes, results due to Torricelli, Fermat, Pascal, Newton, and Leibniz). Each volume is indexed and contains explanatory and historical notes.

COLLECTED PAPERS AND CORRESPONDENCE

This section gathers together editions of works or correspondence of mathematicians. The information comes mainly from various library catalogues and the transcription of names, of title-page information, and of non-English words (especially the Russian language) reflects their various practices. The list is based on the database maintained by Steven W. Rockey at Collected Works:Index (http://www.math.cornell.edu/~library/collectedwks.html) which is regularly updated.

Through the nineteenth century only a relatively small group of people made almost all the important advances in mathematics and collected works volumes exist for most of them. In the twentieth century more people are producing mathematics and the number of collected works has proliferated. The collected works volumes allow the researcher, historian or librarian to have much of the important literature available in a convenient and compact form. Sometimes the collected works volumes are the only way to find articles with obscure citations in titles that are scarcely held even in the most comprehensive libraries. The best collected works volumes may also include unpublished papers, correspondence, commentaries, translations, biographies, bibliographies, etc. that are unavailable anywhere else.

109. Abbe, Ernst Carl, 1840-1905. *Gesammelte Abhandlungen.* Jena: G. Fischer, 1904-1906.

110. Abbe, Ernst, 1840-1905. *Briefe an seine Jugend- und Studienfreunde Carl Martin und Harald Schutz, 1858-1865.* Berlin: Akademie-Verlag, 1986.

111. Abel, Niels Henrik, 1802-1829. *Œuvres complètes de N. H. Abel, mathématicien avec des notes et développements, rédigees par ordre du roi par B. Holmboe.* Christiania: C. Gröndahl, 1839.

112. Abel, Niels Henrik, 1802-1829. *Œuvres complétes de Niels Henrik Abel / Nouv. éd. publiée aux frais de l'Etat norvégien par L. Sylow et S. Lie.* Christiania: Gröndahl, 1881. Reprinted New York: Johnson Reprint Corp., 1973.

113. Adams, John Couch, 1819-1892. *The Scientific Papers of John Couch Adams.* Cambridge: University Press, 1896-1900.

114. Adams, John Frank, 1930-1997. *The Selected Works of J. Frank Adams.* Cambridge: Cambridge University Press, 1992.

115. Ahlfors, Lars Valerian, 1907-1996. *Lars Valerian Ahlfors: Collected Papers / Rae Michael Shortt, assistant editor*. Boston: Birkhäuser, 1982.

116. Ajima, Naonabu, 1739-1798. *Ajima Naonobu zenshu / Hirayama Akira, Matsuoka Motohisa henshu*. Tokyo: Fuji Tanki Daigaku Shuppanbu, Showa 41, 1966.

117. Akaike, Hirotsugu, 1927-. *Selected Papers of Hirotugu Akaike*. Emanuel Parzen, Kunio Tanabe, Genshiro Kitagawa, editors. New York: Springer-Verlag, 1998.

118. Albanese, Giacomo, 1890-1948. *Collected Papers of Giacomo Albanese*. Editors, Ciro Ciliberto, Paulo Ribenboim and Edoardo Sernesi. Kingston, Ontario: Queen's University, 1996.

119. Albert, Abraham Adrian, 1905-1972. *Collected Mathematical Papers*. Providence, R.I.: American Mathematical Society, 1993.

120. Aleksandrov, Aleksandr Danilovich, 1912-1999. *Selected Works / A. D. Alexandrov*. Edited by Yu. G. Reshetnyak and S. S. Kutateladze; translated from the Russian by P. S. V. Naidu. Amsterdam: Gordon and Breach Publishers, 1996-.

121. Aleksandrov, Pavel Sergeevich, 1896-1982. *Izbrannye trudy*. Moskva: Nauka, 1978-1979.

122. Alembert, Jean Lerond d', 1717-1783. *Opuscules mathématiques, ou Mémoires sur différent sujets de géométrie, de mechanique, d'optique, d'astronomie & c.*. Paris: David, 1761-1880.

122.1. Alembert, Jean Lerond d', 1717-1783. *Correspondance inedité de D'Alembert: avec Cramer, Lesage, Clairaut, Turgot, Castillon, Beguelin, etc.* Rome: Imprimerie des Sciences mathématiques et physique, 1886.

123. Alexits, György, 1899-1978. *Approximation Theory: Selected Papers / George Alexits*. Editor Karoly Tandori, co-editors, Dezso Kr'alik, et al. Budapest: Akadémiai Kiadó, 1983.

124. Anderson, Theodore Wilbur, 1918-. *The Collected Papers of T. W. Anderson, 1943-1985*. Edited by George P. H. Styan. New York: John Wiley & Sons, Inc, 1990.

125. Andreotti, Aldo, 1924-1980. *Selecta de opere di Aldo Andreotti*. Pisa: Scuola normale superiore, 1982-.

126. Andronov, Aleksandr Aleksandrovich, 1901-1952. *Sobranie trudov / Otv. red. M. A. Leontovich*. Moskva: Izd-vo Akademii nauk, 1956.

127. Angheluţă, Theodor, 1882-1964. *Opera Matematică*. Bucureşti: Editura Academiei Republicii Socialiste Romania, 1970.

128. Apollonius of Perga, ca. 262-ca. 190 B.C. *Apollonii Pergaei quae graece exstant cum commentariis antiquis / Edidit et latine interpretatus est I. L. Heiberg*. Lipsiae: B. G. Teubneri, 1891-1893. Reprinted Stutgardiae: Teubner, 1974.

129. Archimedes, ca. 287-212 B.C. *Archimedis qua supersunt omnia cum Eutocii Assaionitae commentariis / Ex recensione Josephi Torelli. Veronensis, cum nova versione latina. Accedunt lectiones variantes ex codd. mediceo et parisiensibus*. Oxonii: e typographeo clarendoniano, 1792.

130. Archimedes, ca. 287-212 B.C. *Archimede / Texte établi et traduit par Charles Mugler*. Paris: Les Belles Lettres, 1970-72.

131. Archimedes, ca. 287-212 B.C. *Les Œuvres complétes d'Archiméde suivies des commentaires d'Eutocius d'Ascalon. Traduites du grec en francais avec une introduction et des notes par Paul Ver Eecke*. Liége: Vaillant-Carmanne, 1960.

132. Archimedes, ca. 287-212 B.C. *Opera omnia, cum commentariis Eutocii / Tterun edidit Johan Ludvig Heiberg, corrigenda adiecit Euangelos S. Stamatis*. Editio stereotypa editionis, 1910-. Reprinted Stutgardiae: In aedibus B. G. Teubneri, 1972-.

133. Archimedes, ca. 287-212 B.C. *Opere di Archimede a cura di Attilio Frajese*. Torino: Unione tipografico-editrice torinese, 1974.

134. Archimedes, ca. 287-212 B.C. *Werke. Ubers. und mit Anmerkungen versehen von Arthur Czwalina*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1963.

135. Archimedes, ca. 287-212 B.C. *The Works of Archimedes / Edited in modern notation, with introductory chapters by T. L. Heath*. Cambridge: University Press, 1897.

136. Archimedes, ca. 287-212 B.C. *The Works of Archimedes / Edited in modern notation, with introductory chapters by T. L. Heath. With a supplement, The method of Archimedes, recently discovered by Heiberg*. New York: Dover, 1950.

137. Arf, Cahit, 1910-1997. *The Collected Papers of Cahit Arf*. Turkish Mathematical Society, 1990.

138. Aristotle, 384-322 B.C. *Mathematics in Aristotle / Sir Thomas Little Heath*. Oxford: Clarendon Press, 1949.

139. Aristotle, 384-322 B.C. *The Works of Aristotle translated into English under the Editorship of W. D. Ross*. Oxford: Clarendon, 1908-1952.

140. Arnauld, Antoine, 1612-1694. *Œuvres*. Paris: S. D'arnay, 1775-1783.

141. Arnold, V. I., 1937-. *Singularity Theory: Selected Papers / introduction by C. T. C. Wall*. Cambridge: Cambridge University Press, 1981.

142. Artin, Emil, 1898-1962. *Collected Papers. Edited by Serge Lang [and] John T. Tate*. Reading, Mass.: Addison-Wesley Pub. Co, 1965.

143. Arzela, Cesare, 1847-1912. *Opere scelte; a cura dell'Unione matematica italiana*. Roma: Edizioni cremonese, 1992.

144. Atiyah, Michael Francis, 1929-. *Collected Works*. Oxford: Clarendon Press, 1988.

145. Aubert, Karl Egil, 1924-1991. *Collected Papers of Karl Egil Aubert.* Kingston: Ont., Queen's University, 1992.

146. Babbage, Charles, 1791-1871. *Mathematical Papers.* New York: New York University Press, 1989.

147. Baire, René, 1874-1932. *Œuvres scientifiques / René Baire / publiées sous la direction de Pierre Lelong avec la collaboration de Pierre Dugac.* Paris: Gauthier-Villars, 1990.

148. Ball, Sir Robert Stawell, 1840-1914. *Reminiscences and Letters.* Edited by his son W. Valentine Ball. London, 1915.

Includes a study of Ball's mathematical papers by E. T. Whittaker.

149. Banach, Stefan, 1892-1945. *Œuvres, avec des commentaires. Comité de rédaction: A. Alexiewicz [et al.].* Warszawa: Édition scientifiques de Pologne, 1967-1979.

150. Barbilian, Dan, 1895-1961. *Opera matematică.* Bucureşti: Editura didactică şi pedagogică, 1967-1970.

151. Barrow, Isaac, 1630-1677. *The Geometrical Lectures of Issaac Barrow, with notes and proofs, and a discussion on the advance made therein on the Work of his predecessors in the infinitesimal calculus, by J. M. Child. Chicago: Open Court Publishing Company, 1916.*

152. Barrow, Isaac, 1630-1677. *The Mathematical Works of Isaac Barrow / Ed. for Trinity College by W. Whewell. Cambridge: University Press, 1860.*

153. Barrow, Isaac, 1630-1677. *The Mathematical Works / Edited by W. Whewell.* Hildesheim: Olms, 1973.

154. Bartlett, Maurice Stevenson, 1910-. *Essays on Probability and Statistics.* London: Methuen, 1962.

155. Bartlett, Maurice Stevenson, 1910-. *Selected Papers of M. S. Bartlett.* Edited by R. G. Stanton, E. D. Johnson, D. S. Meek. Winnipeg: Charles Babbage Research Centre, 1989.

156. Battaglini, Giuseppe, 1826-1894. *Giuseppe Battaglini: raccolta di lettere (1854-1891) di un matematico al tempo del Risorgimento d'Italia.* Bari: Levante, 1996.

157. Baur, Carl Wilhelm von, 1820-1894. *Mathematische und geodätische Abhandlungen / von C. W. V. Baur.* Stuttgart: K. Wittwer, 1890.

158. Bellman, Richard Earnest, 1920-1984. *The Bellman Continuum: a Collection of the Works of Richard E. Bellman.* Edited by Robert S. Roth. Singapore: World Scientific, 1986.

159. Beltrami, Eugenio, 1835-1900. *Opere matematiche di Eugenio Beltrami. Pubblicate per cura della Facoltà di scienze della R. Università di Roma.* Milano: U. Hoepli, 1902-1920.

160. Bernoulli, Daniel, 1700-1782. *Die Werke / von Daniel Bernoulli; im Auftrag der Naturforschenden Gesellschaft Basel und der Otto-Spiess-Stiftung; ediert von David Speiser.* Basel: Birkhäuser, 1982-.

161. Bernoulli, Jakob, 1654-1705. *Die Werke von Jakob Bernoullli. (Textkritische Ausg.) Hrsg.von der Naturforschenden Gesellschaft in Basel.* Basel: Birkhäuser, 1969-.

162. Bernoulli, Jakob, 1654-1705. *Jacobi Bernoulli, Basileensis, Opera.* Genevæ: sumptibus hæredum Cramer & fratrum Philibert, 1744.

163. Bernoulli, Jakob, 1654-1705. *Der Briefwechsel von Jacob Bernoulli.* Basel: Birkhauser, 1993.

164. Bernoulli, Jakob, 1654-1705. *Die Streitschriften von Jacob und Johann Bernoulli: Variationsrechnung.* Basel: Birkhäuser, 1991.

165. Bernoulli, Johann, 1667-1748. *Der Briefwechsel von Johann Bernoulli / Hrsh. von der Naturforschenden Geselschaft in Basel.* Basel: Birkhäuser, 1955-.

166. Bernoulli, Johann, 1667-1748. *Johannis Bernoulli . . . opera omnia, tam antea sparsim edita, quam hactenus inedita.* Lausannæ& Genevæ: sumptibus M. M. Bousquet & sociorum, 1742.

167. Bernoulli, Johann, 1667-1748. *Opera omnia.* Hildesheim: Olms, 1968.

168. Bernstein, Serge Natanovich, 1880-1968. *Sobranie sochinenii.* Moskva: Izd. akademii nauk, 1952-54.

169. Bernstein, Serge Natanovich, 1880-1968. *Collected Works.* Oak Ridge: Tenn, U. S. Atomic Energy Commission, Technical Information Service Extension, 1953.

170. Bers, Lipman, 1914-1993. *Selected works of Lipman Bers.* Providence, R.I.: American Mathematical Society, 1998.

171. Bessel, Friedrich Wilhelm, 1784-1846. *Abhandlungen von Friedrich Wilhelm in drei banden.* Leipzig: W. Engelmann, 1875-76.

172. Betti, Enrico, 1823-1892. *Opere Matematiche di Enrico Betti / pubblicate per cura della R. Accademia de' Lincei.* Milano: U. Hoepli, 1903-1913.

173. Beurling, Arne, 1905-1986. *Collected Works of Arne Beurling.* Edited by L. Carleson et al. Boston: Birkhäuser, 1989.

174. Bézout, Etienne, 1730-1783. *Cours de mathématiques, a l'usage de la marine et de l'artillerie.* Paris: Chez Louis, 1795-1801.

175. Bianchi, Luigi, 1856-1928. *Opere. A. cura dell'Unione Matematica Italiana e col contributo del Consiglio nazionale delle ricerche.* Roma: Edizioni cremonese, 1952-1959.

176. Bing, R. H., 1914-1986. *The Collected Papers of R. H. Bing / S. Singh, Steve Armentrout, and Robert J. Daverman editors.* Providence: R.I., American Mathematical Society, 1988.

177. Birkhoff, Garrett, 1911-1996. *Selected Papers on Algebra and Topology.* Edited by Gian-Carlo Rota, Joseph S. Oliveira. Boston: Birkhäuser, 1987.

178. Birkhoff, George David, 1884-1944. *Collected Mathematical Papers.* New York: American Mathematical Society, 1950.

179. Birkhoff, George David, 1884-1944. *Collected Mathematical Papers.* New York: Dover, 1968.

180. Bishop, Errett, 1928-1983. *Selected Papers.* Singapore: World Scientific, 1986.

181. Blaise, Pierre, b. ca. 1717. *Œuvres de mathématiques, ou l'on trouvera les premiers principes du calcul numèrique & algébrique, la géométrie élémentaire des anciens et des modernes.* Paris: G. F. Quillau, 1740.

182. Blaschke, Wilhelm, 1885-1962. *Gesammelte Werke / herausgegeben von W. Burau [et al.].* Essen: Thalesberlag, 1982-1986.

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ARCHIVAL AND SPECIAL COLLECTIONS

Mathematical archives, that is collections of the personal papers of individual mathematicians or of the records of mathematical institutions, can be found in general guides to archival collections described in the reference works by Sheehy, item 1, and Walford, item 2.

872. Parshall, Karen, and Albert C. Lewis.

The web site List of Archival Collections (http://www.ams.org/mathweb/History/collections.html) provides an alphabetical list of mathematicians who are represented by archival collections in North America. No attempt is made to indicate where papers or letters by one person may also be located in the collection of another. Such cross references are often given in the collection descriptions in the indicated sources. This list is part of a site maintained by the American Mathematical Society–Mathematical Association of America Joint Archives Committee.

Information on mathematical archives in the United States may also be obtained from the Archives for American Mathematics, Center for American History, Sid Richardson Hall 2.101, The University of Texas at Austin, Austin, Texas 78712, or Archives of Mathematics and Mathematicians, The John Hay Library, Brown University Library, Providence, Rhode Island 02912.

873. Chowdhury, M. R. "The Apurba Chandra Datta Collection". *Math. Intelligencer* 12 (1990), no. 4, 4.

The Apurba Chandra Datta Collection in the Dhaka University Library, Dhaka, Bangladesh contains many valuable (and quite a few invaluable) titles. Donated to Dhaka (former spelling: Dacca) University in 1962 by the heirs of Apurba Chandra Datta.

874. Davitt, Richard M. "William Marshall Bullitt and His Amazing Mathematical Collection". *Math. Intelligencer* 11 (1989), no. 4, 26–33.

One of the world's most extraordinary collections of first editions of important mathematical works is contained in the William Marshall Bullitt Mathematical Collection of the University of Louisville. This article tells the story of how William Marshall Bullitt assembled this collection of rare mathematical manuscripts.

875. Dorling, Alison R. "The Graves Mathematical Collection in University College London." *Ann. of Sci.* 33 (1976), no. 3, 307–309.

John Thomas Graves (1808–1870), a class fellow of W. R. Hamilton in Dublin, bequeathed his collection of some 14,000 manuscripts, incunabula, pamphlets and books to University College, London. About half the items in the collection pre-date 1500. Some problems in the early part of the twentieth century in keeping the collection might be compared with the problem mentioned in item 877. A description of some of the more unusual items in the collection is given.

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An illustrated and profoundly annotated catalogue of a book exhibition from the rich historical holdings of the Herzog August Bibliothek in Wolfenbüttel. The main sections are entitled Mathematicians (Euclid, Stifel, Gauss), Practical Mathematics, Teaching, Mathematical Disciplines, Recreational Mathematics.

877. Shapin, Steven and Susan Hill. "The Turner Collection of the History of Mathematics at the University of Keele". *British J. Hist. Sci.* 6 (1972/73), no. 23, part 3, 336–337.

The C. W. Turner collection at Keele consists of nearly 1400 items (incunabula, books and pamphlets) illustrating the history of mathematics and allied sciences dating from the late fifteenth century to the mid-nineteenth century. To the surprise of users of this rich resource, the university sold the collection in 1998 to a private collector.

III. GENERAL HISTORIES OF MATHEMATICS

878. Archibald, Raymond Clare. *Outline of the History of Mathematics.* Oberlin, Ohio: Mathematical Association of America, 1949. 6th ed. Supplement to *American Mathematical Monthly* 56 (1) (January 1949). Reprinted New York: Johnson Reprint, 1966.

Originally two lectures given in 1931, numerous additions and changes were made in subsequent editions. See also item 1086.

879. Ball, W. W. R. *Short Account of the History of Mathematics.* New York: Dover, 1960. Reprinted from the fourth edition of 1908. .

First published in 1888, and based, for facts concerning pre-1800 mathematics, on M. Cantor's *Vorlesungen*, item 891. Approximately ten percent of the volume is devoted to the nineteenth century. Often unreliable and needs to be used with considerable caution.

880. Becker, Oscar. *Grundlagen der Mathematik in geschichtlicher Entwicklung.* Freiburg: Alber, 1954. 2nd ed., Munchen, Freiberg, 1964, xi + 427 pp.

With extensive quotations from mathematical and philosophical texts (translated into German), analyzes "the historical development of the problems of the foundations of mathematics from its beginnings to today." See also item 4048.

881. Becker, Oscar, and J. E. Hofmann. *Geschichte der Mathematik.* Bonn: Athenäum-Verlag, 1951.

Described by the authors as a sketch, for those already knowledgeable in the subject, from ancient times to about 1900. H. W. Turnbull, in *Mathematical Reviews* 14 (1953), 341, calls attention to the treatment of Japanese mathematics and the excellent bibliography.

882. Bell, Eric T. *Men of Mathematics.* New York: Simon and Schuster, 1937. Reprinted New York: Simon and Schuster, 1986, xvii + 590 pp.

A popular book, still in print, whose author's highly readable style has to be balanced against an often overimaginative content. This work, like the following item 883, should be used with caution, for Bell's facts are often unreliable, and his conclusions either exaggerated or now out of date. The fact that his works are often the best known among general readers interested in the history of mathematics is all the more reason to verify any assertions that Bell makes. The fact that he rarely offers any documentation often makes it difficult, but all the more necessary, to check the veracity of his assertions.

883. Bell, Eric T. *The Development of Mathematics.* 2nd ed. New York: McGraw-Hill, 1945.

"Not a history of the traditional kind, but a narrative of the decisive epochs in the development of mathematics." Bell gives his analysis of "why certain things continue to interest mathematicians, technologists, and scientists, while others are ignored or dismissed as being no longer vital." Entertaining and popular. Noted for its breadth, clarity, and (sometimes premature) synthesis, but marred by inaccuracies and scanty footnotes. Offers extensive coverage of the 19th century; emphasizes connections between mathematics and the physical sciences. Especially recommended by Sarton for Bell's penetrating mathematical remarks. Many chapters devoted to leading 19th-century mathematicians. Offers almost no documentation; some of its major points have been revised by later scholarship. See for example Tony Rothman, "Genius and Biographers: The Fictionalization of Évariste Galois. *Amer. Math. Monthly* 89 (1982), no. 2, 84–106. "

884. Bochner, S. F. *The Role of Mathematics in the Rise of Science*. Princeton: Princeton University Press, 1966.

Misleading title. Collects together essays which give a personal summary of the history of mathematics from its beginnings to the early twentieth century. The main concern, "the role of mathematics in the rise and unfolding of Western intellectuality," is treated on a higher mathematical level and generally with a less popular appeal than, for example, Morris Kline's *Mathematics in Western Culture*, item 901. Bochner often gives his evaluations of other commentators and historians. Part II consists of about seventy pages of biographical sketches. Indexed.

885. Bolgarskii, B. V. *Ocherki po istorii matematiki.* 2nd ed. Minsk: Vysheishaia Shkola, 1979.

A concise textbook providing many portraits of mathematicians while emphasizing the history of problems.

886. Bourbaki, Nicolas. *Eléments d'histoire des mathématiques.* (Histoire de la pensée IV.) Paris: Hermann, 1960. Nouv. ed. revue, corr. et augm. Paris : Hermann, 1974, 376 pp. Nouv. tirage Paris: Masson, 1984, 376 pp. Translated as *Elements of the History of Mathematics* by John Meldrum, Berlin, New York: Springer-Verlag, 1994, viii + 301 pp.

Gathers together, without substantial change, most of the historical notes accompanying Bourbaki's *Eléments des mathématiques.* Consequently, it provides neither a continuous nor a complete history of mathematics. What it does provide, with emphasis given to modern mathematics, are historical accounts of the evolution of algebra, quadratic forms, topological spaces, real numbers, n-dimensional spaces, complex numbers, metric spaces, infinitesimal calculus, the gamma function, functional spaces, topological vector spaces, and integration, among other topics. However, such important areas as differential geometry, algebraic geometry, and the calculus of variations are not included. Virtually no biographical information is given, but in those areas of mathematics that are considered, special attention is given to formative ideas and how they developed and interacted with other leading mathematical ideas. A bibliography of nearly 300 items is also given. See also items 2298, 2337.

887. Boyer, Carl B. *A History of Mathematics*. New York: John Wiley, 1968. Second ed. revised by Uta C. Merzbach. New York: Wiley, 1989 xviii + 762 pp.

A college-level textbook, with chapter exercises; more extensive in scope than H. Eves, *An Introduction*, item 895, and more historically oriented than Eves, or M. Kline, *Mathematical Thought*, item 902. Includes a chapter on Chinese and Indian mathematics. Though there is a chapter on aspects of 20th-century mathematics in the first edition, consistent detail is given only up to about 1900. Bibliography and 12-page chronological table. The revised edition gives special emphasis to the 19th and 20th centuries. Whole chapters devoted to Gauss and Cauchy, 19th-century geometry, arithmetization of analysis, and the rise of abstract algebra.

888. Bunt, L. N. H., P. S. Jones and J. D. Bedient. *The Historical Roots of Elementary Mathematics*. Englewood Cliffs, N.J.: Prentice-Hall, 1976. Reprinted New York: Dover Publications, 1988, xii + 299 pp.

Contains a history of arithmetic, algebra, geometry, and number systems emphasizing the beginnings in Egyptian, Babylonian, and Greek civilizations. Intended as an elementary introductory textbook for prospective teachers as well as for students with a high school background.

889. Cajori, Florian. *A History of Mathematics*. 1st ed. New York: Macmillan, 1893.4th ed. New York: Chelsea, 1985, viii + 524 pp.

Brings many detailed references up to 1919, the date of the last substantially revised edition. Anonymous editor's additions and a few references and refinements, such as marking names of mathematicians in the index whose collected papers exist, have been added to more recent editions.

890. Cajori, Florian. *A History of Mathematical Notations*. Chicago: Open Court, 1928–1929. 2 vols. Reprinted 1974.

Aims to give "not only the first appearance of a symbol and its origin (whenever possible), but also to indicate the competition encountered and the spread of the symbol among writers in different countries." This is perhaps a unique approach in the literature of the history of mathematics. Volume 1 deals with the notations of elementary mathematics (1. arithmetic and algebra and 2. geometry); volume 2, with higher mathematics (1. arithmetic and algebra, 2. modern analysis, and 3. geometry). The latter volume ends with general reflections on mathematical symbolism. Both volumes are well documented with numerous footnotes; volume 1 is generously illustrated with about 100 facsimiles. There is a detailed table of contents and index. See also item 1892.

891. Cantor, Moritz B. *Vorlesungen über Geschichte der Mathematik*. Leipzig: Teubner, 1880–1908. Reprinted New York: Johnson Reprint Corporation, 1965.4 vols.

This mammoth effort, totalling nearly 3,000 pages in four volumes, is still useful although now somewhat outdated. Volume I (antiquity to 1200 A.D.) emphasizes Greek mathematics, but devotes chapters to the Romans, Hindus, Chinese, and Arabs, and ends with medieval mathematics, including a section on Gerbert. Volume II (1200–1668) is divided into time periods, either by century or half-century, and ends with the work of Kepler, Cavalieri, Descartes, Fermat, Roberval, Torricelli, Wallis, Pascal, Sluse, Hudde, et. al. Volume III (1668–1699) is concerned primarily with the invention and development of the calculus by Newton, Leibniz, and their various adherents, although there are sections on combinatorial analysis, infinite series, algebra, number theory, analytic geometry, and the enormous contributions of Euler. Volume IV (1759–1799) was written with the collaboration of a number of Cantor's contemporaries, including Cajori, Netto, Loria, and Veronese. It covers various topics in separate chapters by given authors (for example, Vivanti did the longest section, on "Infinitesimalrechnung"), and ends with a 20-page general overview of mathematics between 1758 and 1799 by M. Cantor. There are two pages of corrections, and an index (both name and subject). See also commentaries and annotations by Eneström in *Bibliotheca Mathematica*, item 24, as well as items 1154, 1664, 1871.

892. Cooke, Roger. *The History of Mathematics. A Brief Course.* New York: John Wiley, 1997.

In addition to being a reliable account of mathematical achievements the author frankly presents topics of special interest to him and addresses such issues as the importance (or unimportance) of systematic logical exposition, the role of mathematics in applications, its role in society, conditions under which mathematics flourishes and conditions under which it languishes, and people's motivation for doing mathematics.

893. Dedron, P., and J. Itard. *Mathématiques et Mathématiciens*. Paris: Magnard, 1959. English translation, *Mathematics and Mathematicians*, published by Richard Sadler Ltd., 1973. Paperback edition by Open University Press, England, 1978.2 vols.

With extensive quotations from original sources, provides a modern historical survey of classical Greek and European Renaissance (up to 1800) mathematics. Examples are at the elementary level in geometry and algebra. The first volume tries "to show some of the intentions, the hesitations and the doubts in the minds of the greatest thinkers" of pre-Renaissance time.

894. Dubbey, John M. *Development of Modern Mathematics.* London: Butterworths, 1970. Paperbound ed. New York: Crane, Russak, 1975, 145 pp.

Aims "to present the basic facts in the development of mathematics from earliest times to present day." Eighteen references are collected at the end.

895. Eves, Howard. *An Introduction to the History of Mathematics.* 4th ed. New York: Rinehart, 1976. 6th ed. Philadelphia: Saunders College Pub., 1990, xviii + 775 pp.

Intended as a "textbook for a one-semester undergraduate course which meets three hours a week." The mathematical level is only up to the beginnings of calculus. Problems (with solutions) are presented in each section along with bibliographies, and an 8-page chronological table and an index are appended.

896. Grattan-Guinness, Ivor. *The Norton History of the Mathematical Sciences: The Rainbow of Mathematics.* London: Fontana Press, 1997. 817 pp.

Though this comprehensive history is intended for the general reader, it is a rich guide to the historical literature; in particular many of the sections are keyed to the articles by others in the author's *Companion Encyclopedia*, item 10. The author indicates that his history differs from many other general histories of mathematics by giving greater attention to the 19th century and to the importance of applied mathematics, probability and statistics, and by pointing out changes in historical interpretations and noting national differences.

897. Joseph, George Gheverghese. *The Crest of the Peacock: Non-European Roots of Mathematics.* London: Penguin Books, 1990. Reprinted New Delhi: Affiliated East-West Press Pvt. Ltd., 1995.

Sets out to show that mathematics is not a subject just created from next to nothing by the Greeks, then stored by the Muslims and resurrected in the Western European Renaissance. See item 1502 for a description of the contents. The way in which the literature has been used in this book has been criticized by Jens Høyrup in **MR** 92g:01004.

898. Hofmann, Joseph E. *Geschichte der Mathematik.* (Sammlung Goeschen, volumes 226, 875, 882.) Berlin: Walter de Gruyter, 1953–1957. Translated as *Classical Mathematics: A Concise History of the Classical Era in Mathematics* by Henrietta O. Midonick, New York: Philosophical Library, 1959, 159 pp.

Ancient mathematics is covered quickly in order to give greater detail to less well-known areas of medieval and Renaissance mathematics. Volume I covers antiquity through Fermat and Descartes; volume II is devoted to the creation of new methods and developments of the calculus;

volume III carries the history up to the French Revolution. Short bibliographies are given, as well as name and subject indexes.

899. Iseki, Kiyoshi, and M. Kondo. *Modern Mathematics: The Development and the Problems*. Tokyo: Nihon Hyoron, 1977. In Japanese.

Gives brief biographical and bibliographical information on prominent twentieth-century mathematicians, such as the Fields medalists, often accompanied by a photographic portrait. Divided into subject groupings (e.g., abstract algebra, topology, and functional analysis), its purpose is to provide a biographical history of modern mathematics.

900. Katz, Victor. *A History of Mathematics. An Introduction*. New York: HarperCollins, 1993. xiv + 786 pp.

A well-received textbook with emphasis on the multicultural nature of mathematics. It does not, however, give the weight to applied branches of mathematics that some users might want. It is recommended by Struik D. J. in his review in **MR** 94b:01003.

901. Kline, Morris. *Mathematics in Western Culture*. New York: Oxford University Press, 1953. Reprinted London, New York: Oxford University Press, 1964, 484 pp.

On an elementary level advances the thesis "that mathematics has been a major cultural force in Western civilization" by emphasizing mathematical applications in a range of subjects including painting, music, and relativity theory. Illustrated.

902. Kline, Morris. *Mathematical Thought from Ancient to Modern Times*. New York: Oxford University Press, 1972, xvii + 1238 pp. Reprinted New York: Oxford University Press, 1990.

"Emphasizes the leading mathematical themes rather than the men" and excludes Chinese, Japanese, and Mayan civilizations. This is the most complete and the most modern in coverage of the general histories of mathematics. It gives more attention than Boyer's history, item 887, for example, to the first few decades of the twentieth century. Chapter bibliographies and an index are provided. See also items 2225, 2300, 2345, 2720, 3029, 3812.

903. Kowalewski, Gerhard W. H. *Grosse Mathematiker*. Munich: J. F. Lehmanns Verlag, 1938.

A meandering, as the book describes itself, through the history of mathematics from antiquity to the time of the book. While often anecdotal, Kowalewski gives considerable emphasis to the technical side of mathematics.

904. Meschkowski, H. *Problemgeschichte der Mathematik*. Mannheim: Bibliographisches Institut-Wissenschaftsverlag, 1978–1981. 3 vols.

Discusses the "fundamental problems of each epoch" at an undergraduate level, from Chinese and Pythagorean number mysticism to the decidability problem (up to 1950). Roughly evenly divided between quotations from original works and explanations by the author.

905. Smith, David Eugene. *History of Mathematics*. New York: Dover, 1958.Reprinted from the Boston, Ginn and Company, edition of 1951,first published in 1923–1925.2 vols.

Although out of date in many respects, still useful as a source for names, illustrations, and chronology if used in conjunction with more recently written histories. Covers ancient times up to the late nineteenth century. See also item 1876.

906. Struik, Dirk J. *A Concise History of Mathematics*. 3rd rev. ed. New York: Dover, 1967, 195 pp. 4th rev. ed. New York: Dover Publications, 1987, xii + 228 pp.

Covers Oriental, Greek, and Arabic mathematics, and mathematics in the West from its beginnings to the end of the nineteenth century. Third edition is attractively illustrated with pictures of many mathematicians. Also available in translations in numerous foreign languages. Generously illustrated. Index and chapter bibliographies are provided.

907. Wilder, Raymond L. *Evolution of Mathematical Concepts: An Elementary Study*. New York: John Wiley, 1968. Reprinted by Open University Press, 1973. Milton Keynes: The Open University Press, 1978, xx + 216 pp.

Studies the "mathematical subculture from the standpoint of an anthropologist, rather than that of a mathematician" (though the author is also a mathematician). Principal concern is with the development of the concepts of number and geometry, but, as the author adds in a special preface to the Open University paperback edition, this is not a purely historical work. These historical examples are "secondary to furnishing a means for detecting and formulating the nature of the cultural forces affecting the evolution of mathematics." See also item 908.

908. Wilder, Raymond L. *Mathematics as a Cultural System*. Oxford: Pergamon, 1981.

"Describes the nature of mathematics and its relations to society from the standpoint of cultural anthropology." The author intends this as a "more mature treatment" than his *Evolution of Mathematical Concepts*, item 907, "in that citations to mathematical theory are not restricted to number and geometry," and his concepts of hereditary stress and consolidation are related more closely to mathematical developments.

909. Young, Laurence. *Mathematicians and Their Times.* Amsterdam: North-Holland, 1981.

Anecdotal lectures. Most valuable to the historian are probably the personal accounts of the author, professor at the University of Wisconsin, Madison, and Past Fellow of Trinity College, Cambridge. There is an index to persons, but no bibliography and no sources for the quotations are given.

IV. THE HISTORY OF MATHEMATICS: CHRONOLOGICAL PERIODS

ANCIENT MATHEMATICS

EGYPTIAN MATHEMATICS

The main surviving mathematical documents from ancient Egyptian culture date from about 1700 B.C., although the mathematics in them may have been known as early as 3500 B.C. Of chief interest are the Egyptian use of distinct unit fractions to express the result of division, formulas for areas and volumes, and calendar-oriented astronomy.

Documents

Survey of Extant Sources

910. Chace, Arnold Buffum, et al., eds. "Chronological List of Documents". 915 below, 1979, 67.

Lists all known Egyptian mathematical papyri with approximate dates and current locations.

911. Neugebauer, Otto. *The Exact Sciences in Antiquity*. 1st ed. Copenhagen: E. Munksgaard, and London: Oxford University Press, 1951; Princeton: Princeton University Press, 1952. *Reviews*: Dijksterhuis, E. J., **MR** 13, #809a.

Hermelink, H. I., *Zentralblatt für Mathematik* 049.00201.

2nd ed. Providence, R.I.: Brown University, 1957.*Reviews*: Vogel, Kurt, *Byzantinische Zeitschrift* 51 (1958), 414. Reprinted in item 949, 2. Halbband, 860.

MR 19, #825a.

Hermelink, H. I., *Zentralblatt für Mathematik* 084.00201.

Reprinted New York: Harper, 1962.Reprinted New York: Dover, 1969. *Reviews*: Allen, E. B., **MR** 41, #5143.

Hermelink, H. [I.], *Zentralblatt für Mathematik* 084.00201.

Russian transl. *Tochnye nauki v drvnoste*. Moscow: "Nauka", 1968.

The Rhind Mathematical Papyrus (RMP)

Texts

912. Eisenlohr, A. *Ein mathematisches Handbuch der alten Ägypter (Papyrus Rhind des British Museum) übersetzt und erklärt*. Leipzig, 1877. Reprinted Wiesbaden: Sändig, 1972. 2 vols.

913. British Museum Department of Oriental Antiquities. In *Facsimile of the Rhind Mathematical Papyrus.* 1898.

914. Peet, T. E. *The Rhind Mathematical Papyrus, British Museum 10057 and 10058.* London, 1923. Review: *Jahrbuch über die Fortschritte der Mathematik*, 49, 3.

Reprinted, 1978.

915. Chace, Arnold Buffum, et al., eds. *The Rhind Mathematical Papyrus.* Oberlin, Ohio: Mathematical Association of America, 1927–1929.

This work is the most elaborate reproduction of the papyrus, with two-color plates and abundant background and introduction. There is also a comprehensive, annotated, chronological bibliography of commentary on Egyptian and Babylonian mathematics, Volume I, pp. 119–192, with supplement, Volume II, (unpaged), which is listed separately as item 1016. *Reviews*: Vogel, Kurt, *Archeion* 12 (1930), 397–400.

Vogel, Kurt, *Archiv für Geschichte der Mathematik der Naturwissenschaften und der Technik* (1930), 414–427. Reprinted in item 949, 2. Halbband, 827–840.

Vogel, Kurt, *Jahrbuch über die Fortschritte der Mathematik* 55.0594.01.

Abridged reprint, Reston, Va.: National Council of Teachers of Mathematics, 1979. 2 vols.

Does not contain the bibliography of the original (listed separately as item 1016).

916. Robins, Gay and Charles Shute, eds. *The Rhind Mathematical Papyrus: An Ancient Egyptian Text.* With a note by T. G. H. James. London: British Museum Publications, 1979. *Reviews*: Gundlach, K.-B., **MR** 89a:01005. Reprinted in *Zentralblatt für Mathematik* 788.01006.

Reprinted New York: Dover, 1990. **MR** 92j:01003.

917. Guggenbuhl, Laura. "The New York Fragments of the Rhind Mathematical Papyrus". *Mathematics Teacher* 57 (1964), 406–410.

Commentary

918. Vogel, Kurt. *Die Grundlagen der Ägyptishen Arithmetik in ihrem Zusammenhang mit der* 2 : *n Tabelle des Papyrus Rhind.* Dissertation. University of Munich, 1929. Reprinted Wiesbaden: Sändig, 1970.

919. Vogel, Kurt. "Zu zwei Problemen des Rhind Papyrus". *Praxis der Mathematik* 3 (1961), 267. Reprinted in item 949, 2. Halbband, 492.

920. Gillings, Richard J. "Sum of n terms of an arithmetical progression in ancient Egypt". *Australian Journal of Science* 31 (1968/69), 47–48. *Review*: Allen, E. B., **MR** 40, #2490.

921. Roero, Clara Silvia. "Sul problema n. 79 del Papiro Rhind". *Atti della Accademia delle Scienze di Torino. Classe di Scienze Fisiche, Matematiche e Naturali* 111 (1977), 279–283. *Review*: Guggenbuhl, L., **MR** 58, #15804.

922. Gillings, Richard J. "The Recto of the Rhind Mathematical Papyrus: How Did the Ancient Egyptian Scribe Prepare It?" *Archive for History of Exact Sciences* 12 (1974), 291–298. *Abstract*: Gillings, Richard J., *Zentralblatt für Mathematik* 286.01001.

Review: Bruins, E. M., **MR** 58, #1580.

See also item 932.

923. Bruins, Evert M. "On some *hau*–problems. A revision". *Janus* 70 (1983), 229–262.

Examines solutions of linear equations in the RMP. Regarding the $2 : n$ table, Bruins claims that the table does not represent the results of division of 2 by n but rather the representation of the double of a unit fraction as the sum of two different unit fractions.

Reviews: Poizat, Bruno, **MR** 85e:01005.

Gundlach, K.-B., *Zentralblatt für Mathematik* 535.01002.

See also Gillings, items 932 and 944, and entries under Egyptian Fractions.

Moscow Mathematical Papyrus (MMP)

Text

924. Struve, W. W. "Mathematischer Papyrus des Staatlichen Museums der schönen Künste in Moskau". *Quellen und Studien zur Geschichte der Mathematik, Abteilung A: Quellen* 1. Berlin: Springer, 1930. 12 + 198 pp. + 10 pls. *Reviews*: Vogel, Kurt, *Archeion* 13 (1930), 250–251.

Vogel, Kurt, *Deutsche Literaturzeitung* 52 (1931), 1959–1961.

Archibald, R. C., *Isis* 16 (1931), 148–155.

Vogel, Kurt, *Jahrbuch über die Fortschritte der Mathematik* 56.2 for 1939, 801–802.

Peet, T. E., "A Problem in Egyptian geometry", *Journal of Egyptian Archaeology* 17 (1931), 100–106, 154–160.

Neugebauer, O., *Zentralblatt für Mathematik*, 002.00503.

Commentary

925. Vogel, Kurt. "Der moskauer mathematische Papyrus". *Archiv für Geschichte der Mathematik der Naturwissenschaften und der Technik* 13 (1931), 446–463. Reprinted in item 949, 1. Halbband, 77–94.

926. Nims, Charles F. "The Bread and Beer Problems of the Moscow Mathematical Papyrus". *Journal of Egyptian Archaeology* 44 (1958), 56–65.

See also items 985 (concerning volume of a pyramid) and 995 (concerning area of a hemisphere).

Egyptian Mathematical Leather Roll (EMLR)

Texts

927. Glanville, S. R. K. "The Mathematical Leather Roll in the British Museum". *Journal of Egyptian Archaeology* 13 (1927), 232–239, Plates LVIII–LXII.

928. Scott, A., and H. R. Hall. "Egyptian Leather Roll of the 17th Century B.C." *British Museum Quarterly* 2 (1927), 56–57, plate.

929. Glanville, S. R. K. "The Mathematical Leather Roll in the British Museum". In item 915, Vol. II (unpaged).

See also Gillings, item 944, 85–103.

Commentary

930. Vogel, Kurt. "Erweitert die Lederolle unserer Kenntniss Ägyptischer Mathematik?" *Archiv für Geschichte der Mathematik der Naturwissenschaften und der Technik* 11 (1929), 386–407. Reprinted in item 949, 1. Halbband, 4–25.

931. Vogel, Kurt. "Die Algebra der Ägypter des mittleren Reichs". *Archeion* 12 (1930), 126–162. Reprinted in item 949, 1. Halbband, 26–62.

932. Gillings, Richard J. "What is the Relation between EMLR and the RMP Recto?" *Archive for History of Exact Sciences* 14 (3) (1975), 159–167.

The fact that the RMP and the EMLR were discovered together in the same location adds interest to the question of the relationship between the two. Here Gillings suggests that economizing on the space required to represent fractional quantities was the motivating factor in the Egyptians use of unit fractions.

Abstract: Gillings, Richard J., *Zentralblatt für Mathematik* 323.01003.

Review: Bruins, E. M., **MR** 57, #15835.

Claims that Gillings bases his analysis on a wrong deciphering of the contents of the EMLR and that discoveries of papyri in 1980 confirm Bruins's theory that the equalities were constructed by partitioning the lowest common multiples.

933. Gillings, Richard J. "The Recto of the Rhind Mathematical Papyrus and the Egyptian Mathematical Leather Roll". *Historia Mathematica* 6 (1979), 442–447. *Review*: Bruins, E. M., **MR** 81h:01003.

934. Gillings, Richard J. "The Egyptian Mathematical Leather Roll—Line 8. How Did the Scribe Do It?" *Historia Mathematica* 8 (1981), 456–457.

A follow-up to item 932. Here Gillings offers two methods that scribes may have devised in producing Number 8 of the 26 inequalities in the EMLR. See also Gillings, item 944.

Reviews: Ernest, Paul, **MR** 83b:01008.

Bruins, E. M., *Zentralblatt für Mathematik* 475.01001.

Demotic Papyri

Text

935. Parker, Richard A. "Some demotic mathematical papyri". *Centaurus* 14 (1969), 136–141. *Review*: Vogel, Kurt, **MR** 40, #1281.

936. Parker, Richard A. *Demotic Mathematical Papyri.* Providence, R.I.: Brown University Press, 1972. *Reviews*: Vogel, Kurt, *Historia Mathematica* 1 (1974), 195–199. Reprinted in item 949, 2. Halbband, 877–881.

Vogel, Kurt, *Sudhoffs Archiv* 59 (1975), 94–96.

Bruins, E. M., *Zentralblatt für Mathematik* 283.01001.

Commentary

937. Vogel, Kurt. “Die algebraischen Probleme des P. Mich. 620”. *Classical Philology* 25 (1930), 373–375. Reprinted in item 949, 1. Halbband, 63–65.

938. Vogel, Kurt. “Ein arithmetisches Problem aus dem Mittleren Reich in einem demotischen Papyrus”. *Enchoria: Zeitschrift für Demotistik und Koptologie* 4 (1974), 67–70. Reprinted in item 949, 1. Halbband, 685–688.

939. Couchoud, Sylvia. “Essai d’une nouvelle interpretation du premier problème du Papyrus Mathematique Demotique 10520 du British Museum”. *Centaurus* 29 (1986), 1–4. *Review*: Gundlach, K.-B., **MR** 88c:01003.

Works on Egyptian Mathematics in General

940. Gillain, O. *La science égyptienne: L’arithmétique au Moyen Empire.* Brussels: Édition de la Fondation Égyptologique Reine Élisabeth, 1927.

941. Peet, Thomas Eric. “Mathematics in Ancient Egypt”. *Bulletin of the John Rylands Library* 15 (1931), 35ff. *Review*: Neugebauer, O., *Zentralblatt für Mathematik* 002.37801.

942. Van der Waerden, Bartel Leendert. “Die Entstehungsgeschichte der ägyptischen Bruchrechnung”. *Quellen und Studien zur Geschichte der Mathematik, Abteilung B: Studien* 4 (1937–1938), 359–382. *Review*: Neugebauer, O., *Zentralblatt für Mathematik* 019.24203.

943. Lundsgaard, Erik, *Ægyptisk Matematik* Copenhagen: J. H. Schultaz Forlag, 1945. *Review*: Neugebauer, O., **MR** 8, #73g.

944. Gillings, Richard J. *Mathematics in the Time of the Pharaohs.* Cambridge, Mass.: MIT Press, 1972. New York: Dover, 1982.

Suggests that five precepts guided the author of the $2/n$ table of the Rhind Mathematical Papyrus in choosing decompositions: 1. Smaller denominators are preferred, and all are smaller than 1000. 2. Shorter decompositions are preferred, and all are no more than 4 terms long. 3. Smaller denominators precede larger in a decomposition, and never is a denominator repeated. 4. Smallness of the smallest denominator is the main consideration, but a slightly larger smallest denominator is acceptable if it greatly reduces the largest denominator. 5. Even numbers are preferred to odd numbers, even if large, or if the preference lengthens the decomposition. Gillings regards the decomposition of 2/35 as giving a clue to a general method used by the table's author wherever possible, though some decompositions required specialized treatment. *Reviews*: Vogel, Kurt, *Centaurus* 18 (1973), 246–249. Reprinted in item 949, 2. Halbband, 873–876.

Raïk, Anna Eremeeva, *Historia Mathematica* 1 (1974), 464–468.

Guggenbuhl, L., *Isis* 64 (1973), 533–534.

Bruins, E. M., *Janus* 59 (1972), 239–248.

Guggenbuhl, L., **MR** 57, #9396.

Reprinted in *Zentralblatt für Mathematik* 491.01004.

945. Gillings, Richard J. "The Mathematics of Ancient Egypt". In *Dictionary of Scientific Biography.* XV, Supplement 1. Edited by Charles C. Gillispie New York: Scribner's, 1978, 681–705.

See item 8.

946. Korostovtsev, M. A. *The Science of Ancient Egypt.* Moscow: "Nauka", 1982. In Russian. *Review*: Allen, E. B., **MR** 87b:01004.

947. Van der Waerden, Bartel Leendert. *Geometry and Algebra in Ancient Civilizations.* New York: Springer-Verlag, 1983. *Reviews*: Fletcher, C. R., **MR** 85b:01001.

Knorr, W. R., "The Geometer and the Archaeoastronomer: On the Prehistoric Origins of Mathematics". *British Journal of the History of Science* 18 (1985), 197–212.

948. Roero, Clara Silvia. "Numerazione e aritmetica nella matematica egizia". In *L'alba dei numeri.* Edited by Wilma Di Palma et al., Bari: Dedalo, 1988, 117–145.

949. Vogel, Kurt. *Kleinere Schriften zur Geschichte der Mathematik.* 2 vols. Edited by Menso Folkerts. Stuttgart: Franz Stern Verlag, 1988.

950. Vogel, Kurt. *Vorgriechische Mathematik.* Vol. I *Vorgeschichte in Ägyptien.* Hannover: Hermann Schroedel Verlag; Paderborn: Verlag Ferdinand Schoningh, 1988.

951. Couchoud, Sylvia. *Mathématiques Égyptiennes. Recherches sur les connaissances mathématiques de l'Egypte pharaonique*. Paris: Le Léopard d'Or. 1993. *Reviews*: Caveing, Maurice, *Historia Mathematica* 22 (1995), 80–83.

Høyrup, Jens, **MR** 97c:01005.

Transcribes some texts in hieratic (including texts from RMP) into hieroglyphic.

Egyptian Fractions

952. Neugebauer, Otto. *Die Grundlagen der Ägyptischen Bruchrechnung*. Berlin: J. Springer, 1926. Review: *Jahrbuch über die Fortschritte der Mathematik* 52 (1926), 4.

This review also lists other reviews of the book up to 1929; this volume of the *Fortschritte* was not published until 1935.

953. Neugebauer, Otto. "Zur Ägyptischen Bruchrechnung". *Zeitschrift für Ägyptische Sprache* 64 (1929), 44–48.

954. Vogel, Kurt. "Zur Frage der Scheffelteile". *Zeitschrift für ägyptische Sprache und Altertumskunde* 66 (1930), 33–35. Reprinted in item 949, 1. Halbband, 74–76.

955. Vogel, Kurt. "Zur Ägyptischen Bruchrechnung". *Archeion* 13 (1931), 42–44. Reprinted in item 949, 1. Halbband, 108–110.

Cites Problem 70 in RMP as evidence that the ancient Egyptians considered the general fraction $2/n$ and the division $2 : n$ of 2 by n as identical.

Review: Dijksterhuis, E. J., *Zentralblatt für Mathematik* 001.32102.

956. Chace, Arnold B. "The Egyptian Fraction Reckoning". *Archeion* 13 (1931), 40–41.

Reacts to Vogel item 931, saying that the Rhind papyrus can be explained without the Egyptians having had the concept of a general fraction, which we cannot prove in any case. The unit fraction is our philosophical construct to describe the process of Egyptian reckoning; but the Egyptians did not develop a theory of unit fractions, they just reckoned.

Review: Dijksterhuis, E. J., *Zentralblatt für Mathematik* 001.32102.

957. Bruins, Evert M. "Ancient Egyptian Arithmetic: $2/N$". *Koninklijke Nederlandse Akademie van Wetenschappen Proceedings, Series A*,

Mathematical Sciences (Amsterdam) 55 (1952), 81–91. Also in *Indagationes Mathematicae* 14 (1952), 81–91.

Neugebauer and van der Waerden hold that the $2/n$ table of the Rhind Mathematical Papyrus was developed gradually—perhaps over centuries. Bruins disagrees, claiming that the table might have been fashioned in an afternoon. He suggests that the author in treating primes confined himself to "direct" decompositions, those in which all but one of the denominators is a multiple of the prime; and that the decompositions could have been effected by means of the method of multipliers, that is, multiplying numerator and denominator by an integer abundant in factors.

Reviews: Dijksterhuis, E. J., **MR** 14, #1.

Vogel, Kurt, *Zentralblatt für Mathematik* 046.00101.

958. Gillings, Richard J. "The Division of 2 by the Odd Numbers 3 to 101 from the Recto of the Rhind Mathematical Papyrus (B. M. 10058)". *Australian Journal of Science* 18 (1955), 43–49. *Abstract*: **MR** 17, #931c.

959. Bruins, Evert M. "Platon et la table égyptienne $2/n$". *Janus* 46 (1957), 253–263.

960. Gillings, Richard J. "The Egyptian 2/3 Table for Fractions. The Rhind Mathematical Papyrus (B. M. 10057–8)". *Australian Journal of Science* 22 (1959), 247–250. *Review*: Kennedy, E. S., **MR** 21, #7135.

961. Gillings, Richard J. "Mathematical fragments from the Kahun Papyrus". *Australian Journal of Science* 29 (1966), 126–128. *Review*: Allen, E. B., **MR** 40, #2489.

962. Rising, Gerald R. "The Egyptian Use of Unit Fractions for Equitable Distribution". *Historia Mathematica* 1 (1974), 73–74; response by R. J. Gillings, 74.

Rising points out (and Gillings agrees) that the uses in the RMP of 2/3 along with unit fractions provide counterexamples to Gillings's observation that "Egyptian fractions allow equal distribution not only of quantity but also in size and number of pieces".

Review: Guggenbuhl, L., **MR** 58, #15803.

Announcement: *Zentralblatt für Mathematik* 278.01002.

963. Bruins, Evert M. “The Part in Ancient Egyptian Mathematics”. *Centaurus* 19 (1975), 241–251.

Restates Bruins's 1944 research results recounted in item 957. Here he refers to the “beautiful multipliers”—doublings of 2 and 3 and the tenfolds—which can account for all of the entries in the $2/n$ table except for $n = 43, 59$, and 97.

Reviews: Guggenbuhl, L., **MR** 56, #5123.

Lam, L. Y., *Zentralblatt für Mathematik* 338.01001.

964. Bruckheimer, M., and Y. Salomon. “Some Comments on R. J. Gillings' Analysis of the $2/n$ Table in the Rhind Papyrus.” *Historia Mathematica* 4 (1977), 445–452; response by Gillings, 5 (1978), 221–227.

Bruckheimer and Salomon criticize Gillings's book, item 944: (1) for carelessness in counting Egyptian fraction decompositions of various kinds in the Rhind Papyrus; (2) for failing to account for all possible decompositions of $2/n$; (3) for partiality toward the scribe's choices of decompositions, in the formulations of Gillings's “precepts” for choosing a decomposition; (4) various other errors. Gillings defends his precepts as deductions from the data, focusing in detail on the cases of 2/35 and 2/95 (“a solitary error” by the scribe) and citing other commentators.

Reviews: Guggenbuhl, L., **MR** 58, #26694.

Bruins, E. M., *Zentralblatt für Mathematik* 389.01001, 389.01002.

965. Campbell, Paul J. “A ‘Practical’ Approach to Egyptian Fractions”. *Journal of Recreational Mathematics* 10 (1977–1978), 81–86.

Explores feasibility of producing an Egyptian fraction decomposition by the method of multipliers.

Review: Šalát, T., *Zentralblatt für Mathematik* 399.10007.

966. Raïk, Anna Eremeeva “On the Theory of Egyptian Fractions”. *Istoriko-Matematicheskie Issledovaniia* No.23 (1978), 181–191, 358. In Russian.

Supports Gillings's claim that all Egyptian decompositions of $2/n$ can be obtained by transformation of $2/101 = 1/101 + 1/202 + 1/303 + 1/606$.

Reviews: Bruins, E. M., **MR** 58, #26743.

Gundlach, K.-B., *Zentralblatt für Mathematik* 419.01002.

967. Campbell, Paul J. “Bibliography of Algorithms for Egyptian Fractions”. 1979, 21 pp.; revised 1998. Available from the author (Beloit College, Beloit, WI 53511, USA).

Indexed bibliography of articles dealing with algorithms for Egyptian fraction decompositions.

968. Van der Waerden, Bartel Leendert. "The $(2:n)$ Table in the Rhind Papyrus". *Centaurus* 23 (1980), 259–274.

Contends that "quite satisfactory" answers to how the $2:n$ table was obtained were given years ago by Vetter, Neugebauer, and van der Waerden himself. Presents condensed version of item 942, tracing the table entries mainly to Egyptian division and the method of multipliers. The author formerly thought the table was the culmination of a long historical process, but here is inclined to attribute it to a single ingenious individual.

969. Bruins, Evert M. "Egyptian Arithmetic". *Janus* 68 (1981), 33–52.
Reviews: Ernest, Paul, **MR** 83a:01003.

Busard, H. L. L., *Zentralblatt für Mathematik* 474.01001.

970. Knorr, Wilbur R. "Techniques of Fractions in Ancient Egypt and Greece". *Historia Mathematica* 9 (1982), 133–171.

Other writers have debated alleged esthetic criteria underlying the Egyptian computations; by contrast, van der Waerden, items 942, 979, and 968, has stressed the purely technical character of these computations. Although the Greek evidence is rarely brought to bear on this question, this study seeks to show that this evidence strongly upholds his position.

Review: Bruins, E. M., *Zentralblatt für Mathematik* 485.01002.

971. Bruins, Evert M. "Reducible and Trivial Decompositions Concerning Egyptian Arithmetics". *Janus* 68 (1981), 281–297.

Criticizes Gillings's analysis in item 944. Describes a newly rediscovered and reconstructed papyrus that, according to the author, demonstrates his "Platonic" system for systematic decomposition of fractions. "Trivial" decompositions are ones of the form $2/n = 1/x + 1/y + \cdots$ with $x = n$, while "reducible" decompositions are ones in which some of the parts can be summed to an aliquot part, such as $1/z + 1/t = 1/u$.

Abstract: Bruins, E. M., *Zentralblatt für Mathematik* 478.01002.

Review: Waterhouse, William C., **MR** 84c:01003.

972. Rizzi, Bruno. "Il calcolo frazionario egiziano : parte prima". In *Incontri sulla matematica*. Edited by Bruno d'Amore. Roma: Armando, 1986, 37–52.

973. Gardner, Milo. "Babylonian and Egyptian Mathematics, an Egyptian Historical Gap", (in four instalments); "Breaking the RMP 2/nth

Table Code [revised version of second instalment]" (http://www2.ecst.csuchico.edu/~atman/Misc/horus-eye.html) 1995.

Unrefereed postings to Internet. Claims that all prime denominators in the RMP follow a rule similar to Bruins's method of multipliers, in which all but one of the denominators of the expansion is a mutliple of the prime. Proposes details of the calculational procedure for the multiplier method, using $2/p = 1/a + (2a - p)/ap$ and partitioning $(2a - p)$ into suitable divisors of ap. Claims that in 2000 B.C., the Egyptians knew and fully used general fractions. Cites the Akhmin Papyrus (500 A.D.) as using approaches based on $z/p = 1/a + (za - p)/ap$ and on $z/pq = 1/a + (za - pq)/apq$.

974. Brown, K. S. "The Rhind Papyrus 2/N Table" (http://www.seanet.com/~ksbrown/rhindapp.htm) 1995.

Unrefereed posting to Internet. Summarizes Rhind Papyrus representations of $2/n$. Pursues similar explanation to Gardner in item 973, based on $2/p = 1/a + (2a - p)/ap$. Claims that for $n = 35$ and 91, composite cases that are not "sieved out" based on their smaller prime factor, the Egyptians reverted to a "harmonic–arithmetic" decomposition

$$\frac{2}{pq} = \frac{2}{A(p,q)H(p,q)} = \frac{2}{p+q}\left(\frac{1}{p} + \frac{1}{q}\right) = \frac{1}{(p+q)p} + \frac{1}{(p+q)q},$$

where $A(p,q) = (p+q)/2$ and $H(p,q) = 2/(1/p + 1/q)$. The author presents an intriguing table that suggests a relationship to double triangular numbers (ones of the form $k(k+1)$).

975. Brown, K. S. "The Akhmin Papyrus" (http://www.seanet.com/~ksbrown/akhmin.htm) 1995?.

Unrefereed posting to Internet. Analyzes decompositions of n/p from the Akhmin Papyrus (500 A.D.) for $p = 17$ and $p = 19$ compares and suggests a method by which the author could have devised a decomposition into with the smallest maximum denominator. Offers a "meta-table" that can be used to find such decompositions for general n and p with little effort.

Egyptian Geometry

General Commentary

976. Neugebauer, O. "Die Gometrie der aegyptischen mathematischen Texte". *Quellen und Studien zur Geschichte der Mathematik, Abteilung B: Studien* 1 (1931), 1413–451. *Review*: Dijksterhuis, E. J., *Zentralblatt für Mathematik* 002.32304.

977. Luckey, P. "Was ist ägyptische Geometrie?" *Isis* 20 (1933), 15–52.

Discusses symmetry and regularity. *Review*: Neugebauer, O., *Zentralblatt für Mathematik* 007.38602.

978. Wheeler, Noel F. "Pyramids and Their Purpose". *Antiquity* 9 (1935), 5–21, 161–189, 292–304.

979. Van der Waerden, Bartel Leendert. *Ontwakende Wetenschap. Egyptische, Babylonische en Griekse Wiskunde*. Groningen: Noordhoff, 1950. *Review*: Struik, D. J., **MR** 12, #38a.

English translation: *Science Awakening*. Translated by Arnold Dresden with additions by the author. Groningen: Noordhoff, 1954. 2nd ed. New York: Oxford University Press, 1961. 4th English ed. Leyden: Noordhoff, 1975. German translation: *Erwachende Wissenschaft: Ägyptische, babylonishce und griechische Mathematik*, Basel: Birkhäuser, 1956. *Announcement*: **MR** 18, p. 268.

See particularly pp. 31–35 in 2nd English ed. See also item 1165.

980. Gillings, Richard J. In item 944, 137–153, 185–201.

Problems on areas and volumes, pyramids and truncated pyramids, and areas of semicylinder and hemisphere, from various papyri.

Area of a Circle

981. Bruins, Evert M. "Over de Benandering van $\pi/4$ in de Aegyptische Meetkunde". *Koninklijke Nederlandse Akademie van Wetenschappen, Proceedings, Series A, Mathematical Sciences* (Amsterdam) 48 (1945), 206–210. Also in *Indagationes Mathematicae* 7 (1945), 11–15. *Announcement*: *Zentralblatt für Mathematik* 60.00501.

982. Engels, Hermann. "Quadrature of the Circle in Ancient Egypt". *Historia Mathematica* 4 (1977), 137–140.

Offers a simple construction to explain the Egyptian approximation of $(16/9)^2$ for π. *Abstract*: Engels, Hermann, *Zentralblatt für Mathematik* 356.01002.

Review: Guggenbuhl, L., **MR** 56, #5124.

983. Gerdes, Paulus. "Three Alterate Methods of Obtaining the Ancient Egyptian Formula for the Area of a Circle". *Historia Mathematica* 12 (1985), 261–268. *Reviews*: Francis, Richard L., **MR** 86k:01004.

Murawski, R., *Zentralblatt für Mathematik* 571.01002.

984. Robins, Gay and Charles C. D. Shute. "Mathematical Bases of Ancient Egyptian Architecture and Graphic Art". *Historia Mathematica* 12 (1985), 107–122. *Reviews*: Høyrup, Jens, **MR** 87c:01002.

Gundlach, K.-B., *Zentralblatt für Mathematik* 571.01003.

Surveying suggests that the slopes of the pyramids were determined in practice as described in the RMP, from the *seked* of the sides, giving rise to slopes of $5.5 : 7 \approx 0.7857$ and $5.25 : 7 = 0.75$. That the first of these approximates $\pi/4 \approx 0.7854$, say the authors, is merely a coincidence.

Volume of a Truncated Pyramid

985. Gunn, B., and T. Peet. "Four geometrical problems from the Moscow Mathematical Papyrus". *Journal of Egyptian Archaeology* 15 (1929), 167–185. *Review*: Vogel, Kurt, *Mitteilungen zur Geschichte der Medizin und der Naturwissenschaften* 29 (1930), 70–71.

986. Vogel, Kurt. "The Truncated Pyramid in Egyptian Mathematics". *Journal of Egyptian Archaeology* 16 (1930), 242–249. Reprinted in item 949, 1. Halbband, 66–73.

987. Thomas, W. R. "The Moscow Mathematical Papyrus, Number 14". *Journal of Egyptian Archaeology* 17 (1931), 50–52. *Review*: Neugebauer, [O.], *Zentralblatt für Mathematik* 002.00504.

988. Neugebauer, O. "Das Pyramidenstumpf-Volumen in der vorgriechischen Mathematik". *Quellen und Studien zur Geschichte der Mathematik, Abteilung B: Studien* B 2 (1933), 347–351. *Announcement*: *Zentralblatt für Mathematik* 007.145001.

989. Vetter, Quido. "Problem 14 of the Moscow Mathematical Papyrus". *Journal of Egyptian Archaeology* 19 (1933), 16–18. *Announcement*: *Zentralblatt für Mathematik* 007.04901.

990. Vilenkin, N. Ya. "Calculation of the Volume of a Truncated Pyramid in Ancient Egypt" *Istoriko-Matematicheskiye Issledovaniya* No. 28 (1985), 123–125, 349. In Russian. *Reviews*: Gundlach, K.-B., **MR** 87d:01004.

Bruins, E. M., *Zentralblatt für Mathematik* 578.01001.

991. Velpry, Christian. “Le secret de la pyramide”. *Diagrammes* 18 (1987), CV1–CV17. Update on the article “The secret of the pyramid”. *Diagrammes* 19 (1988), i. In French.

Discusses how the the formula for the volume of a pyramid may have been devised.

Reviews: Gundlach, K.-B., **MR** 89e:01005.

Bruins, E. M., *Zentralblatt für Mathematik* 657.01004.

Bruins notes that he arrived at the same drawing and reasoning in his own item 981, and Velpry acknowledges the priority in the subsequent “update”.

MR 90a:01005.

992. Giacardi, Livia, and Tullio Viola. “Saggio su un possibile calcolo dei volumi di alcuni poliedri nella matematica egizia”. *Atti della Accademia delle Scienze di Torino. Classe di Scienze Fisiche, Matematiche e Naturali* 111 (1977), 523–537. *Review*: Guggenbuhl, L., **MR** 58, #4781b.

993. Giacardi, Livia, and Tullio Viola. “Il calcolo dei volumi del trunco di piramide nella matematica egizia. Discussione sulle ipotesi piu impportanti gia proposte”. *Atti della Accademia delle Scienze di Torino. Classe di Scienze Fisiche, Matematiche e Naturali* 111 (1977), 441–453. *Review*: Guggenbuhl, L., **MR** 58, #4781a.

Volume of a Sphere

994. Seidenberg, A. “On the Volume of a Sphere”. *Archive for History of Exact Sciences* 39 (1988), 97–119. *Review*: Gundlach, K.-B., **MR** 89j:01012.

Area of a Hemisphere

995. Gillings, Richard J. “The Area of the Curved Surface of a Hemisphere in Ancient Egypt”. *Australian Journal of Science* 30 (1967–1968), 113–116.

Concerns interpretation of MMP Problem 10, in which there are several lacunae. The review surveys previous interpretations but concludes that the meaning of the problem is still uncertain.

Review: Allen, E. B., **MR** 42, #5751.

996. Fletcher, F. N. R. “The Area of the Curved Surface of a Hemisphere in Ancient Egypt”. *Mathematical Gazette* 54 (1970), 227–229.

Egyptian Astronomy

Text

997. Parker, R. A., and Otto Neugebauer. *Egyptian Astronomical Texts*. London: Lund Humphreys, 1960–1969. 3 vols. *Announcement*: Vol. 1: *Zentralblatt für Mathematik* 113.00104.

Reviews: Vol. 1: Bruins, E. M., *Isis* 53 (1962), 523–525.

Vogel, Kurt, *Sudhoffs Archiv* 47 (1963), 492–494.

Vol. 2: Pingree, David, *Isis* 57 (1966), 136–137.

Vogel, Kurt, *Sudhoffs Archiv* 49 (1965), 101–102.

Fleckenstein, J. O., *Zentralblatt für Mathematik* 121.00402.

Vols. 1–2: Vogel, Kurt, *Archiv für Orientforschung* 21 (1966), 109–111. Reprinted in item 949, 2. Halbband, 865–867.

Commentary

998. Antoniadi, E. M. *L'astronomie égyptienne*. Paris: Gauthier-Villars, 1934. *Announcement*: *Zentralblatt für Mathematik* 009.38806.

999. Bruins, Evert M. "Egyptian Astronomy". *Janus* 52 (1965), 161–180.

Attempts to show that the Egyptian system of decans was more precise than indicated by Parker and Neugebauer. *Reviews*: Toomer, G. J. **MR** 39,#12.

Gundlach, K.-B., *Zentralblatt für Mathematik* 178.29401.

1000. Van der Waerden, Bartel Leendert. *Erwachende Wissenschaft. Band 2: Die Anfänge der Astronomie*. Basel, Boston, Stuttgart: Birkhäuser Verlag, 1965. *Announcement*: **MR** 39, #14.

Reviews: Vogel, Kurt, *Deutsche Literaturzeitung* 89 (1968), 741–744.

Science Awakening II: The Birth of Astronomy. New York: Oxford University Press, 1974. Significantly revised English ed. 2nd. German ed. Basel, Stuttgart: Birkhäuser Verlag. 1980. *Reviews*: **MR** 83a:01004.

Eelsalu, H., *Zentralblatt für Mathematik* 499.01002.

Probuzhdayushchayaska nauka. II. Rozhdenie astronomii. Russian transl. by G. E. Kurtik, based on the 1974 English ed. Moscow: "Nauka", 1991. *Announcement*: **MR** 92m:01009.

See especially pp. 8–45 in the 1974 revised English ed.

1001. Van der Waerden, Bartel Leendert. "Ägyptische Planetenrechnung". *Centaurus* 16 (1971/72), 65–91. *Review*: Guggenbuhl, L., **MR** 57, #15837.

1002. Neugebauer, Otto. *A History of Ancient Mathematical Astronomy. Book III: Egyptian Astronomy.* Berlin, Heidelberg, New York: Springer-Verlag, 1975.

"Egypt has no place in a work on the history of mathematical astronomy." See also item 1163. *Review*: Swerdlow, N. M., *Historia Mathematica* 6 (1979), 76–85.

1003. Slosman, Albert. *L'astronomie selon les Égyptiens.* Paris: Laffont, 1983.

1004. Waerden, B. L. van der. "The motion of Venus in Greek, Egyptian, and Indian texts". *Centaurus* 31 (1988), 105–113.

1005. Kurtik, G. E. "Astronomy of Ancient Egypt". *Istoriko-Astronomicheskiye Issledovaniya* 22 (1990), 207–256. In Russian. *Reviews*: Rosenfeld, B., **MR** 93b:01004.

Eelsalu, H., *Zentralblatt für Mathematik* 722.01001.

Eelsalu translates the author as saying that "mathematical methods were almost not resorted to in seeking solutions for astronomical problems," and that the most interesting mathematical "exercise" was uniform division of the combined length of day and night.

1006. Christiansen, H. Dalgas. "Decanal star tables for lunar houses in Egypt?" *Centaurus* 35 (1992), 1–27.

Reanalyzes later Ramesside star tables and finds that the tables divide the sky into 27–29 regions, rather than 24, and that they list lunar houses rather than hours.

1007. Clagett, Marshall. *Ancient Egyptian Science.* Vol. 2: *Calendars, Clocks, and Astronomy.* Philadelphia: American Philosophical Society, 1995. *Reviews*: Høyrup, Jens, **MR** 96i:01007.

Grundlach, K.-B., *Zentralblatt für Mathematik* 873.01001.

Relations with Greek Mathematics

The earlier literature is substantial; we note here only the more recent work.

1008. Bernal, Martin. *Black Athena: The Afroasiatic Roots of Classical Civilization*. Vol. 1: *The Fabrication of Ancient Greece: 1785–1985*. New Brunswick, N.J.: Rutgers University Press, 1987.

"Afrocentrism," as espoused by Bernal in this context, claims that elements of science and mathematics in Egypt gave rise to, or critically influenced, Greek mathematics and science. Moreover, Bernal attributes lack of recognition of African influence on European science and mathematics to racism on the part of scholars. Bernal's methods in the history of science, which "do not require proof, merely strong possibility," lead him to claim that the Egyptians used π or the golden ratio $\phi = (1+\sqrt{5})/2 \approx 1.618$ in the construction of pyramids.

1009. Bernal, Martin. "Animadversions on the origins of Western science". *Isis* 83 (1992), 596–607.

1010. Palter, Robert. "Black Athena, Afro-centrism, and the History of Science". *History of Science* 31 (1993), 227–287. *Review*: Cook, Donald, **MR** 94i:01001.

1011. Bernal, Martin. "Response to a paper by R. Palter; 'Black Athena, Afro-centrism, and the History of Science'". With comments by Palter. *History of Science* 32 (1994), 445–468. *Review*: Cook, Donald, **MR** 96c:01005.

Palter rejects both Bernal's claims of Afrocentrism and the charge of racism.

1012. Obenga, Theophile. *La Géometrie égyptienne. Contribution de l'Afrique antique a la matheématique mondiale*. Paris: L'Harmattan; Gif-søur-Yvette: Khepera, 1995. *Announcement*: *Zentralblatt für Mathematik* 869.01002.

1013. Lefkowitz, Mary R., ed. *Black Athena Revisited*. Chapel Hill, N. C.: University of North Carolina Press, 1996.

See also item 1004.

Relations with Babylonian Mathematics

The earlier literature is substantial; we note here only the more recent work.

1014. Damerow, Peter. "Die Entstehung des arithmetischen Denkens: Zur Rolle der Rechenmittel in der altägyptischen und der altbabylonischen Arithmetik". In *Rechenstein, Experiment, Sprache: Historische Fallstudien zur Entstehung der exakten Wissenschaften*. Edited by

Peter Damerow, and Wolfgang Lefevre. Stuttgart: Klett-Cotta, 1981, 11-113.

1015. Ritter, James. *Chacun sa verité: Les mathématiques en Égypte et en Mésopotamie*. Paris: Bordas, 1989. *Measure for Measure: Mathematics in Egypt and Mesopotamia*. Oxford: Blackwell Reference, 1995.

Guide to Further Literature

1016. Archibald, Raymond Clare. "Bibliography of Egyptian Mathematics". In item 915, Vol. II.

Splendid comprehensive annotated bibliography through 1929.

1017. Guggenbuhl, Laura. "Mathematics in Ancient Egypt: A checklist (1930–1965)". *Mathematics Teacher* 58 (1965), 630–634.

Most references are to general works on Egyptian culture or mathematics. There are no annotations.

1018. May, Kenneth O. *Bibliography and Research Manual of the History of Mathematics*. Toronto: University of Toronto Press, 1973, 611–615.

Indexes articles reviewed in the major review journals through 1965–1966. Relevant headings under "Historical Classifications: Egyptian" are "General", "Fractions", "Moscow papyrus", and "Rhind papyrus". Article titles are omitted. See also item 14.

MESOPOTAMIAN MATHEMATICS

Many of the works discussed in the chapter on (The History of) Babylonian Mathematics in the first edition of this bibliography (1984) have been omitted in the present revised version, in favor of more recent and more up-to-date bibliographical items. Moreover, in recognition of the considerable widening of the scope of the subject in the last couple of decades, the chapter has been renamed Mesopotamian Mathematics.

The matter of chronology, both recent and ancient, is of great importance in any bibliography devoted to works on (the history of) Mesopotamian mathematics, in the former case because the state of our knowledge about the subject is strongly dependent on the number of mathematical cuneiform texts that have been excavated and published at any given point in time, and in the latter case because, obviously, the nature of the subject changed in the course of time, from the fourth to the first millennium B.C. Therefore the following bibliography is arranged with the titles of books and articles in chronological rather than alphabetical order, and with separate sections for pre-Babylonian, Old Babylonian, and Late Babylonian mathematics. There are also brief additional sections for Mathematics and metrology in peripheral regions, and for Babylonian astronomy.

General Surveys

1019. Neugebauer, Otto. *Vorlesungen über Geschichte der antiken mathematischen Wissenschaften, I: Vorgriechische Mathematik.* Berlin: Springer, 1934, 240 pp.

Published in connection with the editing of volume I of Neugebauer, item 1052. Contains, in addition to a chapter on Babylonian mathematics in general, three interesting chapters on "Babylonian techniques of computation," "General history, language, and writing," and "Number systems".

1020. Gandz, Solomon. "The Origin and Development of the Quadratic Equations in Babylonian, Greek, and Early Arabic Algebra". *Osiris* 3 (1937), 405–557.

This comparative study is based solely on Neugebauer, item 1052, and Thureau-Dangin, item 1053.

1021. Neugebauer, Otto. *The Exact Sciences in Antiquity.* 1st ed. Copenhagen: E. Munksgaard, and London: Oxford University Press, 1951; Princeton: Princeton University Press, 1952.

Treats Babylonian mathematics and astronomy, in particular investigating the possibility of Babylonian influence on Egyptian and Greek or Hellenistic scientific achievements. See also item 1162.

1022. Vogel, Kurt. *Vorgriechische Mathematik, II: Die Mathematik der Babylonier.* Hannover: H. Schroedel, 1959, 93 pp.

A comprehensive and clear account of all (at the time) known aspects of Sumero-Babylonian mathematics, in some parts based on the author's own contributions in a number of smaller papers. Cf. item 1024.

1023. Friberg, Jöran. *A Survey of Publications on Sumero-Akkadian Mathematics, Metrology and Related Matters (1854–1982).* Gothenburg: Chalmers University of Technology, 1982. xv + 155 pp. *Review*: Poizat, Bruno, **MR** 84g:01010.

A bibliographic study (144 typewritten pages) containing a fairly complete list of works (until 1982) on Sumero-Akkadian number systems, metrology, and mathematics. (Works on astronomy are not taken into account.) The publications are arranged chronologically, starting with the first decipherment of cuneiform number signs in the mid 19th century. Almost all entries are accompanied by commentaries detailing their contents and appraising their value in the light of related works. Some include personal opinions of the author, especially the commentaries on the more recent publications.

1024. Vogel, Kurt. *Kleinere Schriften.* Edited by M. Folkerts. Stuttgart, 1988. 2 vols.

These two volumes of collected "minor" works contain (in particular) about twenty brief papers or reviews concerned with Mesopotamian mathematics, written by Kurt Vogel between 1933 and 1962, yet still quite valuable and eminently readable.

1025. Høyrup, Jens. "Algebra and naive geometry. An investigation of some basic aspects of Old Babylonian mathematical thought". *Altorientalische Forschungen* 17 (1990), 27-69, 262-354.

Definitely a corner-stone in the recent new approach to the history of Babylonian mathematics. The author himself describes his goals with this paper in the following words: "Through a broad structural analysis and a close reading of Old Babylonian mathematical 'procedure texts' dealing mainly with problems of the second degree it is shown that Old Babylonian 'algebra' was neither a 'rhetorical algebra' dealing with numbers and arithmetical relations between numbers nor built on a set of fixed algorithmic procedures. Instead, the texts must be read as 'naive' prescriptions for geometric analysis–naive in the sense that the results are seen by immediate intuition to be correct... The investigation involves a thorough discussion and re-interpretation of the technical terminology of Old Babylonian mathematics, elucidates many terms and procedures which have up to now been enigmatic, and makes many features stand out which had not been noticed before.... The last chapter investigates briefly the further development of Babylonian 'algebra' through the Seleucid era, demonstrating a clear arithmetization of the patterns of mathematical thought, the possible role of Babylonian geometrical analysis as inspiration for early Greek geometry, and the legacy of Babylonian 'algebraic' thought to Medieval Islamic algebra." Of particular importance is the ingenious analysis here of the two Susa texts TMS IX and XVI, badly published in Bruins and Rutten, item 1059. Text XVI is shown to be a didactical discussion of various transformations of linear equations of two unknowns, while text IX is shown to be a similar didactic discussion of simplifying transformations of "second-degree" equations.

1026. Høyrup, Jens. "Mathematics, algebra, and geometry". In *The Anchor Bible Dictionary.* Vol. IV. Edited by D. N. Freedman. New York, etc.: Doubleday, 1992, 602–612.

An attempt to describe the mathematical traditions current in the ancient Middle East and in the Hellenistic world at the periods of time when the Old and the New Testament were written. The following are the main topics: A. The "folk" substratum, B. Babylonian mathematics, C. Syrian descendants, D. Egyptian mathematics, E. Greek and Hellenistic mathematics and its aftermath.

1027. Friberg, Jöran. "Numbers and Counting in the Ancient Near East". In *The Anchor Bible Dictionary.* Vol. IV. Edited by D. N. Freedman. New York, etc.: Doubleday, 1992, 1139-1146.

A brief survey of the following topics: A. Number representations and arithmetic in 1. the pre-literate Middle East, 2. the ancient Mesopotamia, 3. the ancient Iran, 4. the ancient Egypt, and 5. the ancient Syro-Palestine; B. Numbers in 1. Sumero-Akkadian legends, 2. Ugaritic legends, and 3. the Bible.

1028. Friberg, Jöran. "Mathematik". *Reallexikon der Assyriologie und Vorderasiatischen Archäologie.* 7 (1993), 531-585.

A lexicon article covering in some detail the development of Mesopotamian mathematics during the more than 3000 years of its existence, from the first proto-Sumerian texts to the final Late Babylonian clay tablets. The manuscript was completed in the summer of 1990. It is divided into six chapters: 1. The main publications of mathematical cuneiform texts; 2. Numbers and fractions: systems of notations, basic arithmetic; 3. Numbers and fractions: evolution; 4. 3rd millennium texts; 5. 2nd and 1st millennium texts; 6. Transmission and diffusion. Published here for the first time is a copy of a small Old Akkadian clay tablet (2300 B.C.) with a drawing which demonstrates a pre-Babylonian origin of the "equi-partition of trapezoids", an important "number-theoretical" problem known from various Old Babylonian mathematical texts.

The reader should be warned that in spite of its general scope this compactly written survey may not be suitable as a first, introductory text.

1029. Nemet-Nejat, Karen Rhea. *Cuneiform Mathematical Texts as a Reflection of Everyday Life in Mesopotamia.* (sr American Oriental Series). Vol. 75. New Haven, CT.: American Oriental Society, 1993, 333 pp.

This book, the first one on Mesopotamian mathematics for over 30 years, does not really contain any useful discussion of the subject, nor any new contributions to it, except for various kinds of surveys, tables, indices, and glossaries. It may be useful as a reference book. Its central part is Ch. 4: "Analysis of the practical problem texts", a commented survey of cuneiform texts or parts of such texts dealing with 23 categories of "practical problems", such as "bricks and brickworks", "canals and irrigation", "defense works", "excavations and earthworks", etc. The indices include a list of cuneiform tablets according to museum numbers, with bibliographical references, and a "glossary of realia". Cf. Robson's critical and constructive review of this book, item 1030.

1030. Robson, Eleanor. Review of K. R. Nemet-Nejat – *Cuneiform Mathematical Texts as a Reflection of Everyday Life in Mesopotamia. Bibliotheca Orientalis* 52 (1995), 424-432. .

A detailed, very informative, and very critical review of Nemet-Nejat, item 1029.

1031. Nissen, Hans J., Peter Damerow, and Robert K. Englund. *Archaic Bookkeeping, Early Writing and Techniques of Economic Administration in the Ancient Near East*. Chicago, London: University of Chicago Press, 1993.

A documentation, for the first time in book form, of a series of recent breakthroughs in current investigations of the Mesopotamian origins of writing, accounting, arithmetic, and mathematics in general. The remarkably elegant and informative publication is written by three experts who in recent years acquired much of that knowledge: Nissen (history and archaeology), Damerow (the history of ideas and the use of computer technology), and Englund (cuneiform writing and ancient administrative techniques). Among the topics dealt with are the following: Pre-literate bookkeeping by means of numerical tokens, tablets, or spherical envelopes of clay; systems of notations for numbers and measures (including measures of time) in proto-literate texts on clay tablets; mensuration and administration of fields in Mesopotamian texts from various periods of the whole third millennium B.C.; detailed accounts of available and expended manpower; an Old Sumerian table of squares, and Old Babylonian multiplication tables, conversion tables for measures, and tables of reciprocals or powers; numbers in traditional notation vs. sexagesimal numbers in place value notation; computer-assisted decipherment and the edition of archaic cuneiform texts. Particularly astounding is the visually clear presentation in the form of an illustrated diagram of the content of a Late Sumerian clay tablet. The text contains the solution of an intricate mathematical problem related to the growth of a herd of cattle over a period of ten years under (implicitly) given initial conditions (four full-grown cows at the beginning of year 1) and growth conditions (a four-year delay before the cows are full-grown, and one calf of alternating sex each year from every pair of full-grown cows). This problem is a very early forerunner of Fibonacci's famous (but less complicated) rabbit problem. Ch. 16 "The development of arithmetic" follows the evolution of Mesopotamian mathematical concepts and techniques from the early stages in the last half of the fourth millennium B.C. to the maturation in the Old Babylonian period in the first third of the second millennium.

1032. Høyrup, Jens. *In Measure, Number, and Weight. Studies in Mathematics and Culture*. New York: State University of New York Press, 1994.

Some parts of this book are concerned with various general aspects of the history of Mesopotamian mathematics: 1.1. "Mesopotamia: Scribal computation and scribal school mathematics.", 2. "Subscientific mathematics: Observations on a pre-modern phenomenon.", 3. "Mathematics and early state formation, or the Janus face of early Mesopotamian mathematics: Bureaucratic tool and expression of scribal professional autonomy."

1033. Caveing, Maurice. *La constitution du type mathématique de l'idéalité dans la pensée grecque. Essai sur le savoir mathématique dans la Mésopotamie et l'égypte anciennes.* Presses Universitaires de Lille, 1994.

The original edition of this work appeared in 1982 as the first part of a dissertation. The stated object of the work is to illuminate the way of thinking of pre-Greek mathematicians, in order to give a proper background to the later "miraculous" appearance of classical Greek mathematics. This is done "through the study of texts chosen among the ones most debated". In his study of Babylonian mathematics, the author often lets divergent interpretations of particularly difficult texts, whether in MKT and TMB, or in commentaries to these works, be confronted with each other, concluding the discussion by giving his own opinion. Unfortunately, the author's unfamiliarity with the English language has prevented him from taking into account more up-to-date commentaries, such as the survey article by Friberg, item 1028, or the important paper Høyrup, item 1025. Probably for the same reason, no references are given to MCT, item 1054.

1034. Høyrup, Jens. "Changing trends in the historiography of Mesopotamian mathematics: An insider's view". *History of Science* 34 (1996), 1-32.

In this supreme introduction to the history of Mesopotamian mathematics is outlined the development of the subject, beginning with the "Heroic Era, 1930 to 1940", when Neugebauer and Thureau-Dangin and their followers (Schuster, Gandz, Vogel), in friendly competition, published and interpreted the bulk of the enormous corpus of cuneiform mathematical texts on Old or Late Babylonian clay tablets, housed in various museums, mostly in the West (London, Paris, Berlin, Strasbourg, Istanbul, and New Haven, CT). The following era, the "Triumph of Translations, 1940 to 1975" was mostly a period of stagnation and decline, although it saw the publication of two additional volumes of Babylonian mathematical texts, the exemplary MCT by Neugebauer and Sachs (item 1054), and the important but far from perfect TMS by Bruins and Rutten (item 1059). The present era, presented as "A Fresh Start from the Sources, Through New Approaches, 1971 onwards", began with Powell's, Friberg's, and Schmandt-Besserat's extension of the subject to include also the study of Sumerian and Proto-Sumerian (more or less) mathematical clay tablets, as well as preliterate tokens. The further development has been closely tied to the activities of several Berlin Workshops on "Concept Development in Babylonian mathematics", organized by Damerow and Englund, and regularly joined by Friberg, J. Høyrup, and others.

1035. Høyrup, Jens. "The finer structure of the Old Babylonian mathematical corpus. Elements of classification, with some results". In *Assyriologica et Semitica, Festschrift für Joachim Oelsner anläßlich seines 65.*

Geburtstages am 18. Februar 1997. Edited by J. Marzahn, and H. Neumann. Kevelaer - Neukirchen-Vluyn, 1998, 117-178.

In Ch. 4 of MCT (item 1054), "The Akkadian dialects of the Old-Babylonian mathematical texts", Goetze showed that Old Babylonian mathematical texts, according to certain characteristic differences in syllabic spelling, can be divided into a "northern" and a "southern" group, or, more precisely, into 6 smaller groups, perhaps originating from different cities (in particular Uruk and Larsa). In this new and extremely thorough study, Goetze's initial grouping of texts is considerably refined and extended, with consideration taken also of differences in vocabulary and phraseology. Two new groups are introduced for texts published after World War II, and therefore of known provenance, the Eshnunna texts (Baqir, item 1057; early Old Babylonian), and the Susa texts (Bruins and Rutten, item 1059; late Old Babylonian). Even the few known Late Babylonian texts are taken into consideration. The outcome of the study is that "the categories, originally based on criteria having nothing to do with the contents of the texts, reflect specific professional environments, endeavors, and even 'schools' with particular canons". Thus, "the classification may function as a grid for the ordering of further observations; a sine qua non if we want to understand the development of Babylonian mathematics".

1036. Robson, Eleanor. *Mesopotamian mathematics 2100-1600 BC: technical constants in bureaucracy and education.* Vol 14 of (Oxford Editions of Cuneiform Texts.) Edited by S. M. Dalley. Oxford: Oxford University Press, forthcoming.

A thorough and comprehensive account of the crucial role played by various kinds of "constants" in many Old Babylonian mathematical texts, as well as in a few Late Sumerian administrative texts. Detailed explanations (several of them new or improved) are given of many of the entries in (in particular) seven Old Babylonian "tables of constants", two of which are new. The appearance and use of such constants in various categories of mathematical problem texts is also discussed, with many explicit examples. These categories include problems in terms of geometry, bricks and brickworks, combined work norms for the making and carrying of bricks, other workloads, grain storing metrology, etc. Two chapters are devoted to mathematics in Late Sumerian and Old Babylonian administration and scribal education, respectively. Several important new mathematical texts are published or discussed here for the first time. There is, however, a considerable measure of overlapping with Friberg (items 1037 and 1071). Particularly noteworthy are new hand copies and discussions of some 50 calculations (more or less mathematically interesting) in texts from Old Babylonian Ur.

1037. Friberg, Jöran. “Bricks and Mud in Metro-Mathematical Cuneiform Texts”. In *Changing Views on Ancient Near Eastern Mathematics.* Edited by J. Høyrup and P. Damerow. forthcoming.

A detailed account of Mesopotamian “brick metrology”, including the function of a special number system for bricks, the unitary relation between weight and volume of bricks, and the meaning of three basic constants for bricks, the “molding number”, the “carrying number”, and the “laying number”. It is shown that there are 19 different textually attested sub-types of bricks, belonging to three main types. All known metro-mathematical cuneiform texts dealing with bricks are systematically analyzed, and it is shown that the typically Mesopotamian type of brick metrology can be traced back at least to the Late Sumerian and Old Akkadian periods.

1038. Ma, Li. *The Rule of False: Early Applications and Conjectured Transmissions.* Dissertation, Chalmers U. of Tech. 1993. iv+123 pp.

A comparative study of how systems of equations in ancient mathematics were often solved through application of the “rule of false”, occasionally even the “rule of double false”. The starting point is an interesting Old Babylonian problem for an arithmetic progression, with a clear parallel in the Egyptian Rhind Papyrus. The investigation is then extended to, in particular, the Chinese classic *Nine Chapters.*

1039. Ma, Li. *Studies of the Rectangular Array Algorithm in Nine Chapters.* Dissertation, Chalmers U. of Tech. 1994. v+156 pp.

One section of this dissertation about one of the chapters in the Chinese classic *Nine Chapters* is devoted to a comparative study of how systems of linear equations were set up and solved in ancient mathematics. Special attention is paid to how the coefficient arrays were chosen. In cuneiform texts, for instance, the arrays are usually triangular, in several cases even bidiagonal.

Chronological Periods

Pre-Babylonian Mathematics and Metrology in the Middle East

There are clear indications that the “Babylonian” mathematicians inherited many of their mathematical methods and traditions from their Sumerian (and other) predecessors in Mesopotamia and surrounding regions. However, very few mathematical texts in the true sense of the word have been preserved from the pre-Babylonian period. Therefore even administrative cuneiform texts from those remote times have to be taken into account when one is trying to study the very early development of mathematical concepts and ideas. In particular, it turns out that it is impossible to understand certain central aspects of the history of Babylonian mathematics without paying due attention to Babylonian and pre-Babylonian metrology. In fact, the history of the

Babylonian sexagesimal system, for instance, is intimately associated with the history of the Sumero-Babylonian metrological number systems for length, area, capacity, and weight.

1040. Edzard, Dietz Otto. "Eine altsumerische Rechentafel (OIP 14, 70)". In *Lišān mithurti, Festschrift W. Freiherr von Soden zum 19. VI. 1968 gewidmet.* Edited by W. Röllig. (Alter Orient und Altes Testament, 1.) Neukirchen-Vluyn: Neukirchener Verlag (Butzon und Kevelaer), (1969), 101–104.

Describes the second oldest known mathematical table, a table for the areas of small squares, expressed in the complicated Sumerian metrological system of area numbers. (From the ancient site Adab, about 2400 B.C.).

1041. Powell, Marvin A., Jr. "The Antecedents of Old Babylonian Place Notation and the Early History of Babylonian Mathematics". *Historia Mathematica* 3 (1976), 417–439.

In this path-breaking paper the author sets out "to show that Babylonian place notation, far from being a creation of the Old Babylonian period (ca. 2000–1600 BC), actually has roots deep in the third millennium and was, in fact, invented before the end of the Third Dynasty of Ur (ca. 2100–2000 BC)." He also makes it clear that "the origins of Babylonian mathematics can now be traced back to the middle of the third millennium BC." In addition to a rich documentation in support of these claims, the paper contains a number of historically interesting notes and remarks.

1042. Høyrup, Jens. "Investigations of an Early Sumerian division problem". *Historia Mathematica* 9 (1982), 19-36.

Considers a metro-mathematical division problem for large numbers solved in two slightly different ways on two early Sumerian tablets, shown as photos and hand copies. Suggests a division "in two steps". Cf. Archi, item 1045.

1043. Whiting, Robert M. "More evidence for sexagesimal calculations in the Third Millennium B.C." *Zeitschrift für Assyriologie* 74 (1984), 59-66.

A set of small mathematical exercise tablets from the Old Akkadian period (2300 B.C.) were discussed in Powell, item 1041. Here two more tablets of the same type are published. One of them is inscribed with a couple of assigned problems, without solutions. The other one contains a problem probably intended to show, in an obvious play with numbers, that a square with the side 3333 rods 3 cubits (where 3 cubits = 1/4 rod) has the area 11110555 1/2 1/16 square rods. The student, however, manages to make a couple of mistakes in his calculations. In addition, he expresses decimal length numbers in terms of Sumerian sexagesimal number notations, and decimal area numbers in terms of (quasi-sexagesimal) Sumerian area number notations. This is just one of several mathematical cuneiform texts demonstrating that there may have been a conflict between habitual counting with decimal numbers in certain elements of the population and the imposed counting with sexagesimal numbers in the Mesopotamian scribal schools. (Cf. Soubeyran, item 1082.)

1044. Friberg, Jöran. "The early roots of Babylonian mathematics 3: Three remarkable texts from ancient Ebla". *Vicino Oriente* 6 (1986), 3-25.

In ancient Ebla in Syria (the last third of the third millennium B.C.), a west-Semitic language (now extinct) was written by use of an imported script, Sumerian cuneiform. In the well-preserved palace libraries of Ebla, four small clay tablets of mathematical interest have been found. Three of them are discussed here: 1. A lexical list with the first ten Sumerian cardinal numbers, written syllabically. 2. Another lexical list, with Sumerian signs for very large sexagesimal number units, from 10.gesh.gal ($10 \cdot 60^2$) to 10.shar.gal ($10 \cdot 60^3$), and 6 times 10.shar.gal (60^4). Here the suffix "gal" implies a shift to the next higher power of 60. The fact that the scribe did not know the sign for the highest number (60^4) is acknowledged through the remark "cannot be counted" (in Sumerian). 3. An explicit computation, possibly a metro-mathematical division exercise, expressed in terms of the local units of capacity measure and the local decimal number system. (Cf. Archi, item 1045).

1045. Archi, Alfonso. "Tables de comptes eblaïtes". *Revue d'assyriologie* 83 (1989), 1-6.

In this paper is published a third pre-Babylonian metro-mathematical division exercise (from Ebla), closely related to the one in Friberg, item 1044 (Ebla) and the one in Høyrup, item 1042 (Sumer). A comparison of the three texts suggests the following series of linked interpretations: In one of the two texts from Ebla it is assumed that 1 1/5 ns-unit of some unnamed commodity X is worth as much as 1 ns-unit of barley. Equivalently, the worth of 24 ns-units of X is 1 gb-unit of barley. What is then the worth of 10,000 ns-units of X? The solution is obtained by use of an ascending recursive division algorithm: 100, 500, 1000, 5000, and 10,000 ns-units of X are worth, respectively, $4, 20\ 1/2, 41\ 1/2, 208$, and 416 1/2 gb-units of barley, with the explicitly indicated remainders 4, 8, 4, 8, and 4 ns-units. (From a modern standpoint, it is interesting to note that the clear periodicity of the algorithm is related to the circumstance that $100/24 = 4.16666\ldots$, a periodic decimal fraction.) In the second division algorithm from Ebla, it is assumed that 33 gb-units of Y are worth 1 gb-unit of barley, and what is asked for is the worth in barley of 260,000 gb-units of Y. (In this case, the clear periodicity of the initial part of the solution algorithm is related to the circumstance that $100/33 = 3.0303\ldots$, another periodic decimal fraction.) In the Sumerian example, only the statement of the problem and the answer are explicitly given. All the barley in a granary holding $5 \cdot 60^3 + 20 \cdot 60^2$ s-units is to be divided into daily rations of 7 s-units each. It is likely that the solution algorithm in this case was of the same type as the ones as in the two Ebla texts, that is, with an initial part where it was shown that $10, 10 \cdot 60, 60^2, 10 \cdot 60^2$, and 60^3 s-units of barley correspond to, respectively, $1, 8, 1 \cdot 60$ 25, $8 \cdot 60$ 34, $1 \cdot 60^2$ $25 \cdot 60$ 42, and $8 \cdot 60^2$ $34 \cdot 60$ 17 rations, with the successive remainders 3, 4, 5, 2, 6, and 1 s-units. (In Babylonian-type sexagesimal relative place value notation, the computation can be interpreted as saying that the reciprocal of 7 is igi $7 = 8\ 34\ 17\ldots$, a non-terminating sexagesimal fraction.)

1046. Schmandt-Besserat, Denise. *Before Writing*. Vol. 1: *From Counting to Cuneiform*. Vol. II: *A Catalog of Near Eastern Tokens*. Austin TX.: University of Texas Press, 1992.

A comprehensive presentation of the author's ideas about tokens as (probably) a powerful tool for counting and accounting, used in the Near East for several millennia before the invention of writing in the late fourth millennium B.C. Volume I provides a general discussion of the theory: what tokens are, how they diversified in the course of time, how they were used, and by whom, how they ultimately came to be tied together on strings or held together in balls of clay, and how they may have inspired the invention of writing. The text is accompanied by many beautiful photographs, by drawings, maps, an extensive set of endnotes, and an index. Volume II is a catalog of some 7000 tokens excavated at 108 sites in five Near Eastern countries, from Iran to Turkey and Israel. An estimated number of 1000 tokens from 7 further sites are known but could not be included for the lack of publishing rights. Part I of Volume I: "The Evidence" and Part 3: "The Artifacts", are both informative and thought-provoking. On the other hand, it is a pity that in a work as important as this, Part 2: "The Interpretation", is full of inaccuracies and unacceptable claims. It is unfortunate, too, that Volume II, while containing a veritable treasure trove of information, is practically useless in the form in which it is published, namely as a crude printout of a computer file in an extremely antiquated format (probably begun as early as in the middle of the 1970's, when the author published the first of a long series of articles devoted to the subject). Reviewed by Friberg in item 1047.

1047. Friberg, Jöran. "Preliterate counting and accounting in the Middle East. A constructively critical review of Schmandt-Besserat's *Before Writing*". *Orientalistische Literaturzeitung* 89 (1994), 477-502.

A careful, partly appreciative, partly very critical review of Schmandt-Besserat's item 1046. The review is accompanied by an independent essay, in which the reviewer tries to correct the worst mistakes in Before Writing, at the same time as much of the information given there (in Volumes I and II) is condensed into a new series of diagrams and tables. Known "proto-cuneiform" number signs (the late fourth millennium B.C.) are compared with the repertory of "simple" tokens found inside sealed clay balls (the middle of the fourth millennium). The tentative conclusion is that the simple tokens of that period can be precisely interpreted as the direct predecessors of those proto-cuneiform number signs which were used for measures of barley on one hand and for sexagesimal, bisexagesimal, or decimal numbers of days or workers on the other. In other words, the tokens in the sealed clay balls may have been accounts of expenditures in grain for work at given work norms (so and so much barley for one day's work) in the case of given numbers of work-days. Proto-cuneiform accounts of the same type are well known (Nissen, Damerow, and Englund, item 1031).

1048. Friberg, Jöran. "Round and almost round numbers in proto-literate metro-mathematical field texts". *Archiv für Orientforschung* 44/45 1997/98, 1-58.

A broad survey of mathematically interesting features in proto-literate "field texts", that is, proto-Sumerian or proto-Elamite texts from around the invention of writing, concerned with quadrilateral fields, the lengths of their sides, their areas, and the seed grain needed for sowing them. It is possible to find in such texts indications of an astonishingly elaborate bureaucratic planning, according to certain fixed sets of rules. Several of the texts are obvious school texts, for instance with unrealistically large or complicated numbers. It is even possible to reconstruct a sophisticated "field-division procedure" used in some of them, apparently a method of successive approximations to a rectangular field of given area and given ratio of the sides. This proto-literate field expansion procedure contained within it the seeds to some of the most important and characteristic aspects of Mesopotamian arithmetic, geometry, and algebra, ranging from the frequent and crucial use of unit fractions and small non-regular numbers such as 7, 11, and 13, to the extensive corpus of problems concerned with "naive geometry" and "metric algebra". (cf. Høyrup, items 1025 and 1067; Friberg, items 1074 and 1077.) Interesting is also the apparent use of multiplicative "constants" (cf. Robson, item 1036), and texts concerned with a form of "proportional distribution" of land (cf. Brack-Bernsen and Smith, item 1065).

1049. Friberg, Jöran. "Proto-literate Counting and Accounting in the Middle East. Examples from Two New Volumes of Proto-cuneiform Texts". *Journal of Cuneiform Studies*, 51 (1999), 1-31.

An essay review of two new additions (by R. K. Englund in the series ATU and MSVO) to the published corpus of proto-literate (proto-cuneiform) Mesopotamian administrative texts. In the review, examples of many different text types are graphically illustrated with copies of clay tablets, and careful explanations are given of the various kinds of number systems appearing in each text type.

The proto-cuneiform number systems discussed are the previously known systems *S* (sexagesimal counting numbers), *B* (bisexagesimal counting numbers), *C* (dry capacity numbers), *T* (time numbers), *A* (area numbers), and *D* (liquid capacity numbers). In addition, the essay contains new explanations of what may be numbers for labor (system *Z*) and weight (system *E*). It is shown that system *E* appears to be an amalgamation of two older number systems for gold and silver, with the relative values 16 and 1, in the same way as the Old Sumerian number system for weights was an amalgamation of two separate number systems for silver and copper, with the relative values 180 and 1.

Old Babylonian Mathematics and Metrology

1050. Hilprecht, Hermann Vollrath. *Mathematical, Metrological and Chronological Tablets from the Temple Library of Nippur.* (Babylonian Expedition of the University of Pennsylvania, Series A, XX:1.) Philadelphia: Dept. of Archaeology, University of Pennsylvania, 1906, 70 pp., 30 + 15 pls.

A pioneering work in the field, in which two groups of mathematical and metrological table texts are published and analyzed in detail; the older is dated to the time of the first dynasty of Isin, i.e., the first subperiod of the Old Babylonian period c. 1900 B.C. Among the tablets are 20 multiplication tables, 3 tables of reciprocals (called "division tables"), one table of squares, one of square roots, and 15 "metrological lists" describing the structure of the current metrological systems and the forms of the corresponding number signs in all possible combinations. Older than all the other tablets is the text CBM 10201, which gives rise to fantastic speculations about the role in Babylonian mathematics of the "Number of Plato". This is simply because the author was unaware of the fact that sexagesimal fractions in Babylonian "relative place value notation" are written in the same form as integers.

The remaining importance of this work is due to the fact that it contains a large number of photos and (extremely beautiful) hand-copies of many kinds of Old Babylonian table texts. Particularly interesting are some examples of texts with a teacher's neat version of a table directly followed by a student's visibly less perfect rendering of the same table.

1051. Thureau-Dangin, François. "La mesure des volumes d'après une tablette inédite du British Museum". *Revue d'Assyrologie* 32 (1935), 1–28.

Presents and discusses the big combined problem text BM 85 196, which contains, apart from a number of stereometric problems, a certain "cane-against-a-wall-problem", known also from a text from the Seleucid period (BM 34 568, see Neugebauer, item 1052, III), and which contains an explicit application of the Pythagorean theorem.

1052. Neugebauer, Otto. "Mathematische Keilschrift-Texte. Vol. I, II". *Quellen und Studien A 3.* Issued in separate volumes, I, II. Berlin: Springer, 1935; "Mathematische Keilschrift-Texte. Vol. III". Berlin: Springer, 1937. Reprinted Berlin, Heidelberg, New York: Springer, 1973, 516 + 64 + 83 pp., 69 + 6 pls.

The classic work in the field. Presents and discusses all mathematical cuneiform texts available to the author up to 1937, many of them published here for the first time.

I: Chapter 1 gives a systematic survey of Babylonian mathematical table texts. The following chapters are devoted to mathematical problem texts or series texts from the Louvre, the British Museum, the museums of Berlin, the Yale Babylonian Collection, etc. II: Contains photographs and hand copies, a text concordance, a bibliography, a date list, Sumerian and Akkadian vocabularies, etc., and a few new texts. III: Contains some complementary material and a "Rückblick" (postscript).

While the many photographs and hand copies of mathematical cuneiform texts in MKT II-III are still beautiful, extremely important, and useful as they are, Neugebauer's translations, glossaries, commentaries, and text interpretations are at best badly organized and difficult to use, but in other cases anachronistic, incorrect or incomplete, and outdated for a variety of reasons. The inexperienced reader is strongly advised to keep this in mind.

1053. Thureau-Dangin, François. *Textes mathématiques babyloniens.* (Ex Oriente Lux, I.) Leiden: J. Brill, 1938, 243 pp.

Duplicates more or less the presentation in Neugebauer, 1051, but contains many improvements of linguistic and other details.

It is unfortunate that quite a few particularly difficult (and therefore particularly interesting) texts or parts of texts that are conscientiously mentioned in MKT I-III are silently omitted by Thureau-Dangin. It is doubly unfortunate that Thureau-Dangin's way of constantly translating Sumerian words and phrases into Akkadian makes it difficult for the reader to know exactly what was written in the original text.

1054. Neugebauer, Otto, and Abraham Joseph Sachs. *Mathematical Cuneiform Texts.* New Haven, Conn.: American Oriental Society and American Schools of Oriental Research, 1945, 177 pp., 49 pls.

An important continuation and complement to Neugebauer, item 1051, mainly occupied with cuneiform mathematical texts from American collections. The first chapter contains information about Babylonian metrology and examples of metrological computations; the second chapter presents various types of mathematical table texts. Chapter 3, Problem texts, begins with a presentation of the important tablet "Plimpton 322," mistakenly called "the oldest preserved document in ancient number theory" (see Friberg, item 1060), some important "series texts", and the first published Old Babylonian "tables of constants" (cf. Robson, item 1036). Chapter 4, by A. Goetze, "The Akkadian Dialects of the

Old-Babylonian Texts", is devoted to an attempted study of the provenance of mathematical cuneiform texts from clandestine excavations, the majority of all mathematical cuneiform texts (cf. Høyrup, item 1035). The volume ends with indexes, a vocabulary, etc.

This volume is much more readable than MKT I-III. In fact, although now in some ways outdated, it can still be recommended as a very good introduction to the subject.

1055. Sachs, Abraham Joseph. "Babylonian Mathematical Texts. I. Reciprocals of Regular Sexagesimal Numbers". *Journal of Cuneiform Studies* 1 (1947), 219–240; "Babylonian Mathematical Texts. II. Approximations of Reciprocals of Irregular Numbers in an Old-Babylonian Text"; "Babylonian Mathematical Texts. III. The Problem of Finding the Cube Root of a Number". *Journal of Cuneiform Studies* 6 (1952), 151–156.

I: A most interesting analysis of three important texts (two of them from Hilprecht's excavations in Nippur around the turn of the century, item 1050) making it clear how the Babylonian mathematicians could compute the reciprocals of many-place regular numbers by use of an iterative algorithm. II: Presents a tablet with a unique Babylonian table of reciprocals of non-regular numbers. The table contains information about what may be the sign of the errors in the round-offs. III: Presents a text with a badly confused example of the applications of a factorization method for finding the cube root of a given number.

1056. Gandz, Solomon. "Studies in Babylonian Mathematics. I. Indeterminate Analysis in Babylonian Mathematics". *Osiris* 8 (1948), 12–40.

Makes an interesting comparison of some parallels in Diophantus to a number of problems in Babylonian mathematics leading to indeterminate equations of the type $x^2 - y^2 = a$ or $x^2 - y^2 = y^2 - z^2$. The author concludes: "There seems to be more depth and significance in Babylonian mathematics than heretofore imagined" and "Babylonian geometry is algebraic and their algebra extends its roots deep into geometry and mensuration.

1057. Baqir, Taha. "An Important Mathematical Problem Text from Tell Harmal". *Sumer* 6 (1950), 39–43, 3 pls.; "Another Important Mathematical Text from Tell Harmal". *Sumer* 6 (1950), 130–148, 5 pls.; "Some More Mathematical Texts". *Sumer* 7 (1951), 28–45, 13 pls.; "Tell Dhiba'i: New Mathematical Texts". *Sumer* 18 (1962), 11–14, 3 pls.

These short papers contain the presentation and preliminary discussion of several small mathematical texts from Eshnunna in the Old Babylonian period. The texts are of considerable mathematical interest in themselves, and even more interesting because they were legally excavated (after World War II), and therefore the first Babylonian mathematical texts with an exactly known provenance and possible to date with some precision. One of the tablets, IM 55357, is devoted to a particularly interesting problem involving a decreasing sequence of similar right triangles obtained by means of a recursive procedure.

1058. Vaĭ man, Aisak A. "Ermitažnaya klinopisnaya matematičeskaya tablička No 015189". (The cuneiform mathematical tablet No. 015189 from the Hermitage). *Epigrafika Vostoka* 10 (1955), 71–83.

Presents a curious tablet from the collections in Leningrad, with a sequence of identical geometric drawings illustrating the use of similarity in setting up a series of geometrical problems from a single set of data. The basic problem is an example of the "equi-partition of trapezoids" (cf. Friberg, item 1028 and Brack-Bernsen and Schmidt, item 1065), and the solutions are what the author calls "Babylonian numbers" (rational solutions of a certain indeterminate equation, closely related to the more well-known Pythagorean equation).

1059. Bruins, Evert M., and Marguerite Rutten. *Textes mathématiques de Suse.* (Mémoires de la Mission Archéologique en Iran, XXXIV.) Paris: P. Geuthner, 1961, 136 pp., 39 + 12 pls.

Presents and discusses 26 mathematical tablets from Susa (the Old Babylonian period), several of them of unusual sophistication. In addition to being of considerable mathematical interest in itself, this collection proves that the knowledge of "Babylonian mathematics" was not confined to Babylonia alone. Of particular interest are two "catalog texts", a text concerned with an "iterated trapezoid partition problem," and some texts involving computations with regular polygons.

In spite of its unique importance, this volume contains only a few photos of clay tablets, less than beautiful and exact hand copies, and nearly worthless text interpretations. Improved interpretations of several of the texts can be found in papers by Friberg (item 1071), Høyrup (items 1025 and 1068), and Muroi (item 1064).

1060. Friberg, Jöran. "Methods and Traditions of Babylonian Mathematics. I: Plimpton 322, Pythagorean Triples, and the Babylonian Triangle Parameter Equations". *Historia Mathematica* 8 (1981), 277–318.

Tries to explain the method of construction of the table Plimpton 322 (Neugebauer and Sachs, item 1055) by reference to a Babylonian factorization method based on the use of regular sexagesimal numbers.

1061. Friberg, Jöran. "Methods and Traditions of Babylonian Mathematics. II. An Old Babylonian Catalogue Text with Equations for Squares and Circles". *Journal of Cuneiform Studies* 33 (1981), 57–64.

Gives an analysis of a text containing a systematic list of linear and quadratic equations, including some of a type otherwise known from

Heron's *Geometrica*: "area, diameter, and circumference of a circle equal to a given number".

1062. Neugebauer, Otto, and Abraham Sachs. "Mathematical and metrological texts". *Journal of Cuneiform Studies* 36 no. 2 (1984), 243–251. Review: Friberg, J., **MR** 87k:01004.

Presents a handful of texts that came to the attention of the authors of MCT too late to be included there. (The manuscript, submitted for publication in 1951, was inadvertently mislaid for 33 years before it was finally published in its original form.) One text is formally arranged like an OB multiplication table of standard type but is inexplicably in complete disorder, with a strange concoction of elements from a table of squares and from one or several multiplication tables. A group of six small tablets contains a series of "metrological exercises", more precisely computations of areas of very small squares, with sides ranging from 2 fingers (5 cm) to 16 cubits (8 m). A small piece (about one sixth) of a large clay tablet is what remains of perhaps the most comprehensive of all known OB combined metrological tables. A plausible reconstruction of the text shows that it comprised at least five separate tables with sexagesimal equivalents of "complete" sets of measures for capacity, weight, area, and length (two variant forms). (See Friberg, item 1076.)

1063. Al-Rawi, Farouk N. H., and Michael Roaf. "Ten Old Babylonian Mathematical Problems from Tell Haddad, Himrin". Sumer 43 (1984 [printed 1987]), 195-218.

The large and perfectly preserved Old Babylonian clay tablet published here is a mixed problem text from the region Eshnunna, precisely dateable because it was found together with several other kinds of clay tablets. It is interesting not least because of it unusual terminology and its use of mathematical "constants" in various "practical" problems. Particularly important are the last two problems, which deal with "mixed work norms" and are key texts for the understanding of numerous Old Babylonian mathematical exercises connected with the making and carrying of bricks (cf. Robson, item 1036 and Friberg, item 1037).

1064. Muroi, Kazuo. "Inheritance Problems of Babylonian Mathematics". *Historia Scientiarum* 34 (1988), 11-19; "Extraction of Cube Roots in Babylonian Mathematics". *Centaurus* 31 (1989), 181-188; "Interest Calculations of Babylonian Mathematics: New interpretations of VAT 8521 and 8528". *Historia Scientiarum* 39 (1990), 29-34; "The Expressions of Zero and of Squaring in the Babylonian Mathematical Text VAT 7537". *Historia Scientiarum* (2) 1 (1991), 59-62; "Small Canal Problems of Babylonian Mathematics". *Historia Scientiarum* (2) 1 (1992), 173-180; "Reexamination of Susa Mathematical Text No. 3: Alleged value $\pi \approx 3\frac{1}{8}$". *Historia Scientiarum* (2) 2 (1992), 45-49; "Reexamination of the First Problem of the Susa Mathematical Text No. 9." *Historia Scientiarum* (2) 3 (1994), 231-233; "Two Harvest problems of Babylonian Mathematics". *Historia Scientiarum* (2) 5 (1996), 249-254; "An Enigmatic Sentence in the Old Babylonian Table of Exponents and Logarithms". *Historia Scientiarum* (2) 6 (1997), 229-230; "A Circular Field Problem in the Late Babylonian Metrological–Mathematical Text W 23291-x". *Ganita Bharati* 19 (1997), 86-90; "Expressions of a Unit in Babylonian Mathematics". *Acta Sumerologica* (Japan) 20 (1998), 121-125; "Early Old Babylonian Mathematical Problems Written in Sumerian". *Historia Scientiarum* (7) 3 (1998), 199-203.

A series of brief but important papers, in which the author, often (but not always) with great success, "applies a half century's advances in the understanding of the Sumerian and Babylonian languages" in order to correct and improve the translations and interpretations of various particularly difficult cuneiform mathematical texts published in MKT (1052) and TMB (1053).

1065. Brack-Bernsen, Lis, and Olaf Schmidt. "Bisectable trapezia in Babylonian mathematics". *Centaurus* 33 (1990), 1-38.

An attempt to reconstruct a suspected Babylonian generating formula for a progression of equi-partitioned trapezoids of the kind appearing in the Old Babylonian text AO 17264. The method used is an odd combination of modern and ancient mathematics, with reference in particular to the well known ingenious solution procedure in VAT 8512. To use the authors' own final words, the attempt made here is "on the verge of good scholarship".

1066. Høyrup, Jens. "The Babylonian cellar text BM 85200+VAT 6599. Retranslation and analysis". In *Amphora: Festschrift für Hans Wussing zu seinem 65 Geburtstag.* Edited by S. Demidov. Basel, etc.: Birkhäuser, 1992, 315–358.

The cuneiform text BM 85200+ is a large fragment of an Old Babylonian, fairly well organized text, where the pretended topic is problems concerned with a "cellar", i. e., a rectangular block with length, width, and depth. Actually, the topic is systems of equations, both linear, quadratic, and cubic. This unique and important text is here for the first time translated into English. The new interpretation of the text is based on two methodological principles, referred to as "structural analysis" and "close reading" (cf. item 1025).

1067. Høyrup, Jens. "'Remarkable numbers' in Old Babylonian mathematical texts: A note on the psychology of numbers". *Journal of Near Eastern Studies* 52 (1993), 281-286.

A survey of the role played by the non-regular numbers 7, 11, 13, 17, 19, together with the regular(!) number 4, and their reciprocals, in cuneiform mathematical texts. It is shown that these "remarkable numbers" usually operate in the multiplicative-partitive domain. In particular, they are favorite tools for setting up complicated first- or second-degree equations.

1068. Høyrup, Jens. "Mathematical Susa texts VII and VIII. A reinterpretation". *Altorientalische Forschungen* 20 (1993), 245-260.

A discussion of two further texts from Susa containing unusually explicit clues to methods and conceptualizations used by Old Babylonian mathematicians (cf. Høyrup, item 1025). Thus, in a first part of text TMS VII it is shown, after a didactical introduction, how to solve a homogeneous indeterminate linear equation. In the second part it is shown how to reduce an inhomogeneous equation to a homogeneous one through a shift of variables. TMS VIII is an equally interesting problem concerned with a couple of mixed second-degree problems. The type of text transliteration presented here, with interlinear translation, is pleasant to the eye and makes a detailed analysis of the text easy. Equally important is the use of the principle of "conformal translation", where translations of terms and phrases are deliberately chosen in such a way that they will represent the language of the original text as closely as possible.

1069. Høyrup, Jens. "On subtractive operations, subtractive numbers, and purportedly negative numbers in Old Babylonian mathematics". *Zeitschrift für Assyriologie* 83 (1993) 42-60.

Just as one can notice a clear distinction in Old Babylonian mathematical texts between two main additive operations ("accumulating" and "appending"; see Høyrup, item 1025), one can find a similar distinction between two subtractive operations ("concrete removal" and "comparison"). This paper contains a detailed survey of all terms for subtractive operations used in mathematical cuneiform texts. It concludes by noting that "negative numbers" do not appear in any such texts.

1070. Nemet-Nejat, Karen R. "Systems for learning mathematics in Mesopotamian scribal schools". *Journal for Near Eastern Studies* 4 (1995), 241-260.

A detailed and updated survey of the three fundamental types of table texts used in the Old Babylonian schools: multiplication tables, tables of reciprocals, and metrological tables (for measures of capacity, weight, area, and lengths). The survey is illustrated by beautiful new photos of multiplication tables (two small single and one large combined), of metrological tables (one small single and one large combined), of two help tables for "equal purchase problems" (see Friberg, item 1028; mistaken for exercises with pairs of reciprocal numbers), of another help table for some practical exercise, possibly involving sections of a canal, and of a small tablet with the computation of the area of a very small square (cf. item 1062).

1071. Friberg, Jöran. "Pyramids and cones in cuneiform and other mathematical texts. New hints of a common tradition in ancient mathematics". *Proceedings of the Cultural History of Mathematics* 6 (1996), 80-95.

An introductory discussion of a new fragment of a cuneiform text from the British Museum which demonstrates that already Old Babylonian mathematicians considered solid figures like pyramids, cones, and related objects, and that they possessed correct formulas for the volumes of such figures. The new text, together with the earlier misunderstood Susa text TMS 14 (both texts also discussed in Robson, item 1036), even makes it clear that the fundamental and non-trivial idea of cutting a triangular prism by an oblique plane into a triangular and a square pyramid was a Babylonian invention. Comparisons are made with similar ideas in the works of Euclid and Liu Hui.

1072. Høyrup, Jens. "The Four Sides and the Area: Oblique light on the prehistory of algebra". In *Vita Mathematica. Historical research and integration with teaching*, ed. R. Calinger. Washington, 1966, 45-65.

In this fascinating essay, the remarkable career of a particular mathematical problem is followed, from its first appearance in an Old Babylonian text until its very last appearance during the Renaissance, three thousand years later, in the works of Luca Pacioli and Pedro Nunez.

The essay begins with the following acute observation: BM 13901 is a large and carefully organized mathematical cuneiform text, with the theme quadratic equations and quadratic-linear systems of equations. One of the problems in this text (to find the side of a square from the sum of the four sides and the area) appears totally out of context and out of character, and may belong to a non-scholarly tradition of mathematical riddles or challenges, carried by practical geometers. The formulation of the problem, with the sides mentioned before the area, the decimal data (the side = 10), the non-standard solution method, and its position near the end of the text, all set this problem apart from the other 23 problems of the theme text.

The unusual solution method reappears as one of two variants of a geometric proof in al-Khwarizmi's algebra. A small group of problems related to, and including, the one about the four sides and the area appears in Abu-Bakr's *Liber mensurationum*, still with the side = 10. Similar groups of problems can be found in Savasorda's *Liber Embadorum*, in Leonardo Fibonacci's *Pratica Geometriae*, and so on.

1073. Fowler, David, and Eleanor Robson. "Square root approximations in Old Babylonian mathematics: YBC 7289 in context". *Historia Mathematica* 25 (1998), 366–378.

Although basically concerned with the very accurate square root approximation $\sqrt{2} \approx 1;24\ 51\ 10$ on a well known round school tablet with a drawing of the diagonals in a square, this paper is of a wider interest. Thus, it demonstrates a previously unknown relation between Old Babylonian teachers' long lists of assigned problems and their students' "hand tablets" onto which these problems were transferred, it discusses the Old Babylonian way of finding good approximations to square roots, and it explains the nature of Old Babylonian tables of constants (or coefficient lists; see item G17). Particularly important is the new interpretation of a previously obscure line in a table of constants as referring to ;26 15, the constant of "a triangle with an eighth part subtracted" (actually, an equilateral triangle with its height equal to $1 - 1/8 = 7/8 =; 53\ 20 \approx \sqrt{3}/4$, and its area equal to $7/16 \approx ; 26\ 15$ if its side is 1). A similar interpretation is given for the constant related to the area of a regular heptagon.

There is a certain overlapping between the discussions of square root approximations in this paper and in item L4. In particular, it is quite remarkable that in the Late Babylonian text discussed in item L4 the constant for the area of an equilateral triangle is given in two ways, first (as in the Old Babylonian example quoted above) as "an equilateral triangle with an eighth part subtracted", then (with a refined approximation) as "an equilateral triangle with a tenth and a thirtieth part subtracted".

Late Babylonian Mathematics and Metrology

1074. Friberg, Jöran, Hermann Hunger, and Farouk Al-Rawi. "'Seed and Reeds': A Metro-Mathematical Topic Text from Late Babylonian Uruk". *Baghdader Mitteilungen* 21 (1990), 483–557 and plates 46–48.

In the latter half of the first millennium B.C., the increasing cosmopolitanism and the astonishingly rapid growth of mathematical astronomy led to a second flowering of Babylonian mathematics. This second flowering coincided with the dying out of Babylonian as a written language and with the abandonment of the durable clay tablets as a medium for writing. As a result, very few Late Babylonian mathematical texts have been preserved; only three such texts were included in Neugebauer's MKT and MCT half a century ago. The situation is doubly unfortunate because the lack of documentation makes it difficult to find out to what extent Late Babylonian mathematics was a direct continuation of the better known Old Babylonian mathematics, or to what extent Late Babylonian mathematics and contemporary classical Greek mathematics influenced each other.

Against this background, it is easy to understand the importance of the new Late Babylonian mathematical text discussed here. It is a full-size clay tablet in four columns, containing a systematic series of mathematical problems related to a common topic, the computation of areas of various plane figures by use of several different methods for area mensuration in use in Late Babylonian Mesopotamia. The first two or three problems are of Old Babylonian type and use the traditional (quadratic) area measure. The very first problem is also closely related to one of the earliest documented accomplishments of Greek mathematics: Hippocrates' celebrated quadrature of lunes.

The remaining problems on the clay tablet are of distinctly Late Babylonian type and use reed measure and seed measure for area mensuration, two methods which were popular in Late Babylonian administrative texts. These problems also have a more advanced logical format than the simple standard format of problems in Old Babylonian texts, which consists of a statement of the problem, with given numerical data, followed directly by a numerical solution algorithm. In the new format, the initial question is followed by a fixed phrase "Since you do not know", an abstract computation rule, and a numerical application of that rule. The conformal transliteration of the text is presented here within an outline of the clay tablet. This new transliteration format has the double advantage that 1. it makes it easy to compare the transliteration (and translation) of the text with the cuneiform original as presented in photo and hand copy, and 2. it makes it easier to see exactly how much of the original text is well preserved and to check the validity of the proposed reconstruction of damaged parts of the text.

1075. Britton, John P. "A table of 4th powers and related texts from Seleucid Babylon". *Journal of Cuneiform Studies* 43-45 (1991-93), 71-87.

A fragment of a mathematical text from an extensive, illegally excavated astronomical archive in Seleucid Babylon. Contains parts of the first twenty lines and the very last line of large tablet with originally about eighty lines of up to 25-place sexagesimal numbers (i.e. numbers with 50 digits). The table is shown here to be a table of "fourth powers", actually squares of squares of all the entries between 1 and 2 in the well known Late Babylonian 6-place table of regular sexagesimal numbers and their reciprocals.

1076. Friberg, Jöran. "On the structure of cuneiform metrological table texts from the -1st millennium". *Grazer Morgenländische Studien* 3 (1993), 383-405.

All twelve known metrological tables from the first millennium B.C. (Assyrian or Late Babylonian) are shown here in conform transliterations within outlines of the clay tablets they were written on. A comparison is made with known metrological tables from the second millennium B.C. (Old Babylonian) where the different kinds of measures usually appear in the order C, M, A, L (capacity, metal or weight, area, length), with the units of measure in a left column and the sexagesimal multiples of a basic unit in a right column. In the Late Babylonian tables, these orders are reversed. Completely new features are "structure tables" for length measures and a "range table" for length and area measures, a "metrological multiplication table" for length and reed measures, and an "equivalence table" for area and seed measures. New are also tables for reed measure, for named shekel fractions, and for shekel fractions equated with multiples of a barley-corn.

1077. Friberg, Jöran. "'Seed and Reeds Continued'. Another metro-mathematical topic text from Late Babylonian Uruk". *Baghdader Mitteilungen* 28 (1997), 251-365, pl. 45-46.

The clay tablet discussed here is a topic text demonstrating various ways of measuring surface content, just like the text discussed in Friberg, et al. (item 1074), of which it appears to be a direct continuation. The four main topics of the text can be described as: 1. Seed measure and the foundations of metric algebra (i.e. geometric statements and solutions of second-degree problems); 2. and 3. A systematic survey of various kinds of mathematical constants for two kinds of seed measure; 4. Symmetric and equilateral triangles and their area measure. The second part of the paper deals with the extraordinary importance of this new cuneiform text for the history of ancient mathematics and metrology. It clarifies, in particular, the probable Babylonian origin of Euclid's "geometric algebra", as well as of various Indian, Egyptian and Greek square root approximations. The indices at the end of the paper include a glossary of Late Babylonian mathematical terms, and an up-to-date survey of the small, but rapidly growing, corpus of Late Babylonian mathematical texts.

1078. Friberg, Jöran. "Mathematical cuneiform texts in the Metropolitan Museum of Art". In *Cuneiform Texts from the Metropolitan Museum of Art*. Vol. 2. Edited by I. Spar, and W. G. Lambert. Forthcoming.

A discussion of five small fragments of Seleucid tables of many-place reciprocal pairs of regular sexagesimal numbers from the illegally excavated astronomical archive in Babylon. The discussion of the fragments is taken as a pretext to treat in detail the question about the content of the original table of which all the others may be copies, and about how the entries of that original table may have been computed. The conclusion drawn is that the construction of this first table of many-place pairs of reciprocals may exceed in sophistication all that is otherwise known from the whole corpus of Babylonian mathematics, with the exception, of course, of Late Babylonian mathematical astronomy. The principal tool of the investigation in this paper is the "index flower", placed in a variant of the index grid originally devised by Neugebauer in order to uniquely represent all regular sexagesimal numbers by points in a plane.

1079. Friberg, Jöran. "A Late Babylonian Factorization Algorithm for the Computation of Reciprocals of Many-place Sexagesimal Numbers". *Baghdader Mitteilungen*, 30 (to appear).

A discussion of eight tabular arrays of many-place sexagesimal numbers appearing on a large fragment of a round school text from Late Babylonian Uruk. It is shown that each tabular array is an example of the application of the "last place algorithm", a clever factorization algorithm for the computation of reciprocals of given many-place sexagesimal numbers. A similar, though Old Babylonian, algorithm is discussed in Sachs (item 1055:I). The eight examples are closely related to the Late Babylonian "twelve-place table of pairs of reciprocal" reconstructed in Friberg (item 1076).

Mathematics and Metrology in Peripheral Regions

1080. Bruins, Evert M., and Marguerite Rutten. *Textes mathématiques de Suse.* See item 1059.

1081. Nougayrol, Jean, et al. *Mission de Ras Shamra. Vol. 16. Ugaritica V.* Paris: Geuthner, 1968.

Ugarit, on the coast of the Mediterranean, flourished between the 15th and 13th centuries B.C. That the city was influenced by the Mesopotamian civilization is demonstrated by some clay tablets published here (143-149) on which Babylonian metrological lists for capacity, weight, and area are noted in the cuneiform script.

1082. Soubeyran, Denis. "Textes mathématiques de Mari". *Revue d'Assyriologie* 78 (1984), 19-48.

Mari was a Mesopotamian outpost at the upper Euphrates, on the route to Syria. A few Old Babylonian mathematical table texts were found there, in some rooms of a palace. Of particular interest is a metro-mathematical table of powers, where a given amount of (probably) silver on the first day is doubled for 30 consecutive days. The initial amount being 2 barley-corns (1/10 of a gram), the result of the computation is 27 37 talents 1/2 mina 2 1/3 shekels 4 barley-corns. (The sexagesimal number 27 37 is, by mistake, written as the decimal number 2737 or, more precisely, 2 thousand 7 hundred 37.)

1083. De Odorico, Marco. *The Use of Numbers and Quantifications in the Assyrian Royal Inscriptions.* State Archives of Assyria Studies, 3, 1995.

The object of this work is to resolve the difficult question of the truthfulness of the many numbers of all kinds appearing in the annals of the Assyrian kings, and in certain related documents. The numbers in question are conveniently arranged by the author into a few main "categories", such as "round numbers", "exact numbers", often the sum of a large, round number and another, much smaller number, "high" and "low" numbers, and "totals", referring either to a single episode or to a repeating series of "homologous" episodes.

Babylonian Astronomy

Works on Babylonian (mathematical) astronomy are generally not taken into account in this bibliographical section, which is intended to deal only with works concerned with Mesopotamian mathematics. See, however, the following two items:

1084. Galter, Hannes D., ed. *Grazer Morgenländische Studien 3: Die Rolle der Astronomie in den Kulturen Mesopotamiens. Beiträge zum 3. Grazer Morgenländischen Symposion (23.-27. September 1991).* Graz, 1993.

1085. Walker, Christoffer B. F. “Bibliography of Babylonian astronomy and astrology”. In *Die Rolle der Astronomie*. Edited by Hannes D. Galter, with additions by Galter and Bernhard Scholz. 1993, 447–445.

GREEK MATHEMATICS

This bibliography treats two aspects of the extensive literature that has been produced on the history of ancient Greek mathematics: roughly half of the entries record either the best available editions of the texts themselves or reliable translations of these into a modern language, while the other half lists histories and studies of various problems or methods of ancient Greek mathematics.

With regard to the editions and translations of the texts, available space precludes even the listing of one translation of each known Greek mathematical work; here the aim has been a comprehensive coverage of only the major treatises with a representative selection of the minor ones. In the case of secondary literature, emphasis has been given to works in English of which the researcher should be aware. From these, studies have been chosen that treat areas where considerable amounts of work still remain to be done, such as the history of numerical methods in Greek mathematics, ancient methods of dealing with arcs of circles on the sphere, the development of geometry that led up to the composition of Euclid’s *Elements* (including the still-murky history of incommensurables and the theory of proportions), infinitesimal methods in ancient Greece, and the many problems still surrounding Archimedesś works.

Thus much of the work undertaken by older generations of scholars such as Bretschneider, Hankel, Tannery, and Zeuthen has been omitted except few cases where they cannot be replaced by recent works, as well as a certain amount of modern European work. However, the reader who pursues the references given here will rapidly discover which of those works are important for his purposes. Finally, the reader will also want to search through the recent literature for further contributions in such periodicals as *Archive for History of Exact Sciences*, *Archives*

Internationales d'Histoire des Sciences, *Centaurus*, and *Historia Mathematica*.

General Reference Works

See also items 12 and 14.

1086. Archibald, Raymond Clare. *Outline of the History of Mathematics.* Item 878.

Contains a 13-page summary of Greek mathematics and a particularly valuable eight-page bibliography on the subject.

1087. Hornblower, S., and A. Spawforth, eds. *Oxford Classical Dictionary.* 3rd ed. Oxford: Oxford University Press, 1996.

Gives good coverage of Greek mathematics (especially biographical aspects) and incorporates results of recent research.

1088. Mugler, C. *Dictionnaire historique de la terminologie géométrique des Grecs.* Paris: C. Klincksieck, 1958–1959. 2 vols.

Records the changing meanings of Greek geometrical terms by supplying, along with definitions, examples of usage from such writers as Euclid, Archimedes, Apollonios, and Pappos, as well as Plato and Aristotle.

1089. *Paulys Real-Encyclopädie der classischen Altertums-Wissenschaft.* Edited by G. Wissowa, et al. Stuttgart: A. Druckenmüller, 1958. 34 vols. + 15 vols. of Supplement.

This monumental work (known as Pauly-Wissowa) was published from 1894 to 1978 and its various articles represent a scholarly introduction to what is known (and conjectured) about every aspect of classical antiquity. While its emphasis is on biography there are also short topical articles. The user should know the following: Volumes 1–24 were published from 1894 to 1963 and cover the letters A–Q. Beginning in 1914 a "Second Series" was published, completed in 1972, covering the letters R–Z. The 15-volume supplement, published from 1903 to 1978, incorporates more recent research relevant to the various articles, and this, with its index, must be consulted if one wants a reasonably recent view of many of the subjects.

1090. *Der kleine Pauly.* Edited by Ziegler, K., and W. Sontheimer. Stuttgart: A. Druckenmüller, 1964. 5 vols.

This is an abridged version of item 1089.

1091. Sezgin, Fuat. *Geschichte des arabischen Schrifttums*, Vol. 5 (Mathematics), and *Geschichte des arabischen Schrifttums*, Vol. 6 (Astronomy). Leiden: E. J. Brill, 1974 (Vol. 5), and 1978 (Vol. 6).

These two volumes are an indispensable source for the study of Arabic manuscripts and printed editions of Greek mathematical and astronomical works (some of which are no longer extant in Greek versions), as well as for translations and studies of these in a variety of languages. See also items 1091, 1237.

Source Materials

Anthologies

1092. Bulmer-Thomas, Ivor. *Selections Illustrating the History of Greek Mathematics.* Cambridge, Mass.: Harvard University Press, 1941. 2 vols. Vol. I revised 1980.

A useful anthology of Greek mathematical texts with English translations in which one may find important passages not easily available elsewhere, and a great help to a person trying to learn to read mathematical Greek.

1093. Cohen, M. R., and I. E. Drabkin. *A Source Book in Greek Science.* McGraw-Hill, 1948.

Practically all the branches of Greek mathematics are well represented by English translations of the relevant texts.

1094. Humphrey, J. W., J. P. Oleson, and A. N. Sherwood. *Greek and Roman Technology: A sourcebook.* Routledge, 1998.

English translation of selected passages concerning ancient technology from 150 authors. It covers, for example, energy, basic mechanical devices, agriculture, mining and metallurgy, hydraulic engineering, transport and trade, and military technology. Only a few passages are cited from mathematical writings: one passage from Archimedes, three from Pappus, twelve from Heron. Athough this may not be a direct proof that mathematics and technology were, by far, less related to each other than they are today, this is at least a proof of our difficulty in studying their relations. Regardless, this work is useful in providing the background of ancient mechanics.

1095. Barker, A. *Greek Musical Writings.* Cambridge University Press, 1984-1989. 2 vols.

Contains English translations of most of the Greek texts concerning music (Vol. 1) and musical theory (Vol. 2). The translations are superior and the annotations valuable.

Individual Mathematicians

Apollonios

1096. Heath, T. L. *Apollonius of Perga. Treatise on Conic Sections, Edited in Modern Notation with Introductions including an Essay on the Earlier*

History of the Subject. Cambridge: The University Press, 1896. Reprinted New York: Dover; Cambridge: W. Heffer, 1961.

The only available English version of the seven surviving books of *The Conics*, but in no sense a translation. Related propositions have been grouped into one, the order of the propositions has been altered and "modern notation" (as of 1896) has been used throughout. Still a useful work, nevertheless.

1097. Heiberg, J. L. *Apollonii Pergaei quae Graece exstant cum commentariis antiquis*. Leipzig: Teubner, 1891, 1893. 2 vols.

The principal edition of the Greek text, with Latin translation, of Books I–IV of Apollonios's *Conics* and the ancient commentaries. Since Eutocios's commentary on Apollonios has not been translated into a modern language the reader with no Greek must rely on Heiberg's Latin translation.

1098. Toomer, G. J., ed. and tr. *Apollonius: Conics Books V to VII*. New York: Springer, 1990. 2 vols.

The first complete text and translation of Books V, VI and VII that are extant only in Arabic translation.

1099. Ver Eecke, Paul. *Les coniques d'Apollonius du Perge . . . avec une introduction et des notes*. Bruges: Desclée, De Brouwer et Cie., 1923.

Provides as literal a translation as possible of the seven extant books of *The Conics* as well as a scholarly introduction summarizing the work, citing the ancient testimonies on Apollonios and recounting the later history of the theory of conic sections. The first four books are translated from item 1097, while books V to VII are based on Halley's Latin translation of 1710.

Archimedes

1100. Dijksterhuis, E. J. *Archimedes*. Copenhagen: Ejnar Munksgaard, 1956. Reprinted with a new bibliographic essay by Wilbur R. Knorr. Princeton: Princeton University Press, 1987.

An edition and study of Archimedes's known works, in which theorems are translated literally while a special notation, avoiding some of the implications of algebraic symbolism, is used to present paraphrases of the proofs. Subsidiary lemmas in the various treatises are grouped together in one chapter. Two chapters on the life of Archimedes and the tradition of the manuscripts open this important study. Reprint edition contains Knorr's comprehensive and useful bibliographycal essay: "Archimedes after Dijksterhuis: A Guide to Recent Studies", that keeps this book up to date.

1101. Dold-Samplonius, Y., H. Hermelink, and M. Schramm. *Archimedes, Über einander berührende Kreise. Aus dem Arabischen übersetzt und mit Anmerkungen versehen.* Stuttgart: Teubner, 1975.

The fourth volume of the set *Archimedis* Opera Mathematica (see item 1103). Dold-Samplonius has published a study of this treatise in *Sudhoffs Archiv* 57 Heft 1 (1973), 15–40, in which she concludes that it is a part of a larger Archimedean work *On Circles*.

1102. Heath, T. L. *The Works of Archimedes with the Method of Archimedes.* Cambridge: The University Press, 1897 and 1912. Reprinted New York: Dover, n.d.

Presents the mathematical arguments in a symbolism that would have been familiar to a 19th-century mathematician, but is still a standard source. The useful introductory chapters on "Arithmetic in Archimedes," "On the Problems Known as ΝΕΥΣΕΙΣ", and "The Terminology of Archimedes" must be supplemented by a study of more recent works on these topics.

1103. Heiberg, J. L. *Archimedis opera omnia cum commentariis Eutocii.* 2nd ed. Leipzig: Teubner, 1910–1915. 3 vols.

This is the standard edition of the Greek text, with Latin translation, of Archimedes's works and is the one most frequently cited. There is a reprint of the text, with some corrections by E. Stamatis, published by Teubner (3 volumes), Stuttgart, 1972, and a four-volume edition of the text, with a French translation by C. Mugler, published by Les Belles Lettres, Paris, 1970–1972.

1104. Ver Eecke, Paul. *Les oeuvres complètes d' Archimède, suivies des commentaires d'Eutocius d'Ascalon.* 2nd ed. Liege: Vaillant-Carmanne, 1960. 2 vols.

The only modern translation which contains the commentaries of Eutocios of Ascalon, an important source for any serious study of Archimedes's works.

Aristarchos

1105. Heath, T. L. *Aristarchus of Samos, the Ancient Copernicus, a History of Greek Astronomy to Aristarchus Together with Aristarchus' Treatise on the Sizes and Distances of the Sun and Moon. A New Greek Text with Translation and Notes.* Oxford: Clarendon Press, 1913.

Though we should have liked Aristarchos's treatise on the heliocentric system to have been preserved, it is, instead, this earlier treatise which has survived. Its use of geometrical methods to handle problems for which trigonometry was later employed is especially interesting.

Aristotle

1106. Heath, T. L. *Mathematics in Aristotle*. Oxford: Clarendon Press, 1949. Reprinted 1970.

A collection of passages from the writings of Aristotle bearing on mathematical topics. See also item 4104.

Autolykos

1107. A. Czwalina, tr. *Autolykos Rotierende Kugel und Aufgang und Untergang der Gestirne. Theodosios von Tripolis Sphaerik. (Ostwald's Klassiker*, No. 232). Leipzig: Akademie Verlagsgesellschaft, 1931.

The first two works, by Autolykos of Pitane, are examples of Greek spherics contemporary with Euclid, and the two books composing the second of these works have been shown by O. Schmidt ("Some Critical Remarks about Autolycus' On Risings and Settings," *Den. 11. skandinaviske matematikerkongress i Trondheim 22–25 August, 1949*, 202–209) to be simply two versions of the same work. For the third work by Theodosios, see item 1145. There is also an English translation, whose renderings cannot always be trusted, by F. Bruin and A. Vondjidis, *The Books of Autolykos, On a Moving Sphere and On Risings and Settings* (Beirut: A. U. B. Press, 1971); and a French translation, Germaine Aujac, *Autolycos de Pitane, La sphère en mouvement; Levers et couchers héliaques; Testimonia* (Paris: Les Belles Lettres, 1979).

Boethius

1108. Friedlein, G., ed. *Anicii Manlii Torquati Severini Boetii De institutione arithmetica libri duo, De institutione musica libri quinque, accedit Geometria quae fertur Boetii.* Leipzig, 1867.

The critical edition of Boethius's works. For translations see item 1109.

1109. Bower, C. M. Edited by C. V. Palisca. *Fundamentals of Music: Anicius Manlius Severinus Boethius. New Haven: Yale University Press, 1989.*

English translation of *De institutione musica*, the most influential music theory throughout the Middle Ages, and even today a source for some information otherwise lost about Greek musical theory.

Diocles

1110. Toomer, G. J. *Diocles on Burning Mirrors: The Arabic Translation of the Lost Greek Original.* Berlin: Springer-Verlag, 1976.

Provides Arabic text and an English translation (with historical introduction) of Diocles's work on burning mirrors as well as bibliographical references to the other major ancient source on burning mirrors, the treatise of Anthemios of Tralles. Included are appendices giving the text and translation of Eutocius's excerpts from *On Burning Mirrors* (taken from Eutocius' commentary to Archimedes (item 1103)), other ancient and medieval proofs of the focal property of the parabola, and expositions of Neugebauer's analysis and proof. See also item 1267.

Diophantos

1111. Heath, T. L. *Diophantus of Alexandria; A Study in the History of Greek Algebra*. Cambridge: The University Press, 1885. Reprinted New York: Dover, 1964.

Really a historical study of the methods and influence of Diophantos's work, the book closes with an 80-page appendix abstracting the problems and solutions in six books of the *Arithmetica* and the treatise *On Polygonal Numbers*. The reprint is of the second edition (1910), which contains a supplement on the contributions of Fermat and Euler to Diophantine problems.

1112. Sesiano, J. *Books IV to VII of Diophantos' Arithmetica in the Arabic Translation of Qusṭā ibn Lūqā*. New York: Springer Verlag, 1982.

This is an English translation, together with an edition of the Arabic text, of what most scholars now regard as Books IV–VII of Diophantos's *Arithmetica*. One result is that we now have 10 of the 13 books of this work, and what Tannery thought were Books IV–VI are, in fact, from the last six books of the *Arithmetica*. Accompanying the text are commentaries of considerable historical, philosophical, and mathematical interest.

1113. Rashed, Roshdi. *Diophante, Les Arithmétiques*. Paris: Les Belles Lettres, 1984. 2 vols. (tome 3 and 4).

French translation and the Arabic text of Books IV–VII of Diophantos's *Arithmetica*, with introduction, modern transcription and commentary.

1114. Tannery, Paul. *Diophanti Alexandrini opera omnia cum Graecis commentariis*. Leipzig: Teubner, 1893–1895. 2 vols.

This is the standard edition of the Greek text of what prior to recent times seemed to be the first six books of Diophantos's *Arithmetica*. It also includes Diophantos's *On Polygonal Numbers*.

1115. Ver Eecke, Paul. *Diophante d'Alexandrie*. Paris: Albert Blanchard, 1959. Reprinted from the original edition of 1926.

A French translation of Diophantos's extant works, both the *Arithmetic* and *On Polygonal Numbers*.

Euclid

1116. Archibald, Raymond Clare. *Euclid's Book on Divisions of Figures: A Restoration Based on Woepcke's [Arabic] Text and on the Practica* *geometriae of Leonardo Pisano*. Cambridge: The University Press, 1915.

The statements of the 36 propositions as well as the proofs of four of them were found by Fr. Woepcke in an Arabic treatise. The Greek text is lost. Archibald restored the remaining proofs on the basis of a medieval Latin work.

1117. Chasles, Michel. *Les trois livres de Porismes d'Euclide*. Paris: Mallet-Bachelier, 1860.

A speculative reconstruction of a lost Euclidean treatise, by a leading 19th-century French geometer, based on references by Pappos, Proclos, Ibn al-Haytham, and others.

1118. Heath, T. L. *The Thirteen Books of Euclid's Elements*. 2nd ed. Cambridge: The University Press, 1926. Reprinted New York: Dover, 1956. 3 vols.

A good English translation of this basic source, including an account of the spurious Books XIV and XV. Notes are eclectic, take into account all the important ancient and modern commentaries.

1119. Vitrac, B. *Euclide. Les Éléments*. Paris: PUF, 1990-1994. 4 vols., 2 vols. to date.

This new French translation of *The Elements*, is no doubt the best among those available in modern languages, because of its up-to-date and adequate references, and clear and concise essays—not short themselves but concise compared with Heath's eloquence.

1120. Heiberg, J. L., and H. Menge, eds. *Euclidis opera omnia*. Leipzig: Teubner, 1883-1916. 8 vols. + Supplement.

Besides the Greek text with Latin translation of genuine and spurious works it gives the Latin translation by Gerard of Cremona of the commentary on the first ten books of *The Elements* written by al-Nayrīzī. The first five volumes that contain the text and the scholia of *The Elements* was re-issued, minus the Latin translation, as *Euclidis Elementa* I–V (Leipzig: Teubner, 1969–1977).

1121. Berggren, J. L., and R. S. D. Thomas. *Euclid's Phaenomena, A Translation and Study of a Hellenistic Treatise in Spherical Astronomy*. New York: Garland Publishing, 1996, x + 132 pp.

English translation, with a good introductory essay, of one of the surviving works by Euclid, closely connected with *On the Moving Sphere* by Autolykos.

1122. Thaer, C. *Die Data von Euklid*. Berlin: Springer, 1962.

A German translation of the Greek text of an influential Euclidean work.

1123. MacDowell, G. L., and M. A. Sokolik. *Data of Euclid, translated from the text of Menge*. Baltimore: Union Square Press, 1993.

An English translation of Euclid's *Data*. See also item 1752.

1124. Ver Eecke, Paul. *Euclide: L'Optique et la Catoptrique*. Paris: A. Blanchard, 1959.

Only the first of the two works mentioned is by Euclid, and this French translation contains, as well, Theon's recension of *The Optics*. The introduction surveys the history of Greek optics and the history of the text.

1125. Barbera, André. *The Euclidean Division of the Canon: Greek and Latin sources*. Lincoln: University of Nebraska Press, 1991.

A new and meticulous critical edition with English translation of Euclid's *Division of the Canon*, and its adaptation in Porphyry and Boethius.

Heron

1126. Bruins, Evert M., ed. *Codex Constantinopolitanus, Palatii Veteris No. 1*, Parts 1–3. Leiden: E. J. Brill, 1964.

The three parts of this work contain photographs of the codex, an edition of the Greek text, and an eccentric translation of the same. Very useful, but treat editorial opinions with caution. The work itself is a collection of the metrical writings of Heron of Alexandria.

1127. Heiberg, J. L., et al. *Heronis Alexandrini Opera quae supersunt omnia*. Leipzig: Teubner, 1899–1914. 5 vols.

The principal edition of the Greek or Arabic texts of the known works of Heron with German translations, containing also numerous selections from other classical writers in the Heronic tradition.

Hipparchus

1128. Manitius, K., ed. *Hipparchi in Arati et Eudoxi Phenomena Commentariorum libri tres*. Leipzig: Teubner, 1894.

The only extant work of Hipparchus, containing criticisms of the works on fixed stars by Eudoxus, Aratus, and Attalus. The data concerning heliacal risings and settings were used for a number of important studies on the origin of the star catalogue in Ptolemy's *Almagest* (cf. items 1216 and 1217).

Iamblichus

1129. Dillon, J., and J. Hershbell, eds. *On the Pythagorean Way of Life*. Atlanta: Scholars Press, 1991.

This book contains the text and English translation, with notes, of the first work of the series *On Pythagoreanism*, that consists of nine or ten books, where Iamblichus aimed to revive and convey the Pythagorean doctrines as he understood them (see item 1202). The first book is the exposition of the way of life of Pythagoras and his followers, and contains a few legends concerning the discovery and secret of incommensurability, that have been so emphasized by later historians.

1130. Romano, F., ed. *Il numero e il divino.* Milano: Rusconi, 1995.

Text and Italian translation of Iamblichus's Book III: *On General Mathematical Science*, Book IV: *On Nicomachus's Arithmetical Introduction* (for these two books this is the only translation avalable in a modern language), and pseudo-Iamblichus's *Theology of Arithmetic* (sometimes identified with, and in any case related to, Iamblichus's lost Book VII: *On Arithmetic in Theological Matters*). This last is translated into English as *The Theology of Arithmetic: on the mystical, mathematical and cosmological symbolism of the first ten numbers attributed to Iamblichus* ; translated from the Greek by Robin Waterfield; with foreword by Keith Critchlow, (Grand Rapids, Mich.: Phanes Press, 1988.)

Menelaos

1131. Krause, M., tr. and ed. "Die Sphärik von Menelaos aus Alexandrien in der Verbesserung von Abū Naṣr Manṣūr b. ʿAlī b. ʿIrāq". *Abhandlungen der Gesellschaft der Wissenschaften zu Göttingen, philol.-hist. Klasse*, 17 3. F. (1936). Issued separately, Berlin: Weidmannsche Buchhandlung, 1936.

Since the Greek text of Menelaos's *Spherics* no longer exists, this edition of the Arabic text, accompanied by a German translation and a thorough study of the history of the text among the Arabs, is especially valuable. See also item 1270.

Nicomachus

1132. D'Ooge, M. L., F. E. Robbins, and L. C. Karpinski. *Nicomachus of Gerasa: Introduction to Arithmetic*. New York: The Macmillan Co., 1926.

Contains an English translation of this late Greek text on number theory as well as studies of Greek arithmetic by the two last-named authors.

Pappos

1133. Hultsch, F., ed. *Pappi Alexandrini Collectionis quae supersunt.* Berlin: Weidmann, 1876–1878. Reprinted Amsterdam: A. H. Hakkert, 1965. 3 vols.

The edited Greek text, with Latin translation and commentary, of the eight existing books of this 4th-century A.D. guide to the classical literature of mathematics by Pappus. For the eighth book the reader should also consult the translation by D. E. P. Jackson of the Arabic version of this book (which contains material not in the present Greek text) in his Cambridge dissertation. (For further details, see Jackson, "The Arabic Translation of a Greek Manual of Mechanics", *Islamic Quarterly* 16 [1972], 96–103.)

1134. Thomson, W., and G. Junge. *The Commentary of Pappus of Alexandria on Book X of Euclid's Elements.* Cambridge, Mass.: Harvard University Press, 1930. Reprinted New York: Johnson Reprint Corporation, 1968.

Since the Greek text of this work is lost, the present translation is based on an Arabic version of the work. See also item 1271.

1135. Paul Ver Eecke, tr. *Pappus d'Alexandrie, La Collection Mathematique.* Paris, Bruges: Desclée, De Brouwer et Cie., 1933.

This is the only complete translation of this work (item 1133) into a modern language.

1136. Jones, Alexander. *Pappus of Alexandria, Book 7 of the Collection.* New York: Springer Verlag, 1986. 2 vols.

This is the most reliable edition with a faithful English translation of Book 7 of Pappus's *Collection*, the most important book dedicated to the domain of analysis. Commentaries and essays on the lost works for which Pappus's lemmata were intended (Apollonius's minor works, Euclid's *Porism*, etc.) are also very helpful.

1137. Rome, A., ed. *Commentaire sur les livres 5 et 6 de l'Almageste.* Rome: Biblioteca Apostolica Vaticana, 1931.

Greek text of Pappus's *Commentary* to Books 5 and 6 of Ptolemy's *Almagest*. See also items 1146, 1147.

Proclos

1138. Manitius, K., tr. and ed. *Procli Diadochi Hypotyposis astronomicarum positonum.* Leipzig: B. G. Teubner, 1909, and G. Friedlein, ed. *Procli Diadochi in primum Euclidis Elementorum librum commentarii.* Leipzig: B. G. Teubner, 1873, translated in G. R. Morrow, tr. *Proclos Diadochos: A Commentary on the First Book of Euclid's Elements.* Princeton: Princeton University Press, 1970. Reprinted with a new foreword by Ian Mueller. Princeton: Princeton University Press, 1992.

These two works by the fifth-century scholar Proclos are valuable sources of historical information. The former work is a good introduction to the planetary models found in Ptolemy and the latter contains among much other valuable material a summary of the early history of Greek geometry composed by Aristotle's pupil Eudemos.

Ptolemy

1139. K. Manitius, tr. *Ptolemäus: Handbuch der Astronomie*. Leipzig: B. G. Teubner, 1963. 2 vols.

This second edition of Manitius's excellent German translation of Ptolemy's *Almagest* is accompanied by a brief foreword and corrections by O. Neugebauer. The reader more comfortable with English will want to use G. Toomer's translation, *Ptolemy's Almagest* (London: Duckworth, 1984).

1140. Heiberg, J. L., ed. *Syntaxis mathematica (Claudii Ptolemaei opera quae exstant omnia, vol.1 pt. 1-2)*. Leipzig: Teubner, 1888–1893.

The Greek edition of Ptolemy's *Almagest*.

1141. Nobbe, C. F. A., ed. *Claudii Ptolemaei Geographia*. Leipzig: C. Tauchnit, 1843–1845. Reprinted Leipzig: Holze, 1898, and Hildesheim: G. Olms, 1966. 3 vols.

A German translation of Book I can be found in H. von Mžik, *Des Klaudios Ptolemaios Einführung in die darstellende Erdkunde, Teil I*, Vienna (1938); this contains F. Hopfner's study of Ptolemy's map projections on pp. 93–105, and of Marinos of Tyre's projection on pp. 87–89.

1142. Düring. *Ptolemaios und Porphyrios über die Musik*. Göteborg: Elanders, 1934. Reprinted New York: Garland, 1980.

Greek text with German translation of music theory of Ptolemy and Porphyry.

1143. Lejeune, A. *L'Optique de Claude Ptolémée, dans la version latine d'après l'arabe de l'emir Eugène de Sicile*, Leiden, 1956. Reprinted Leiden: Brill, 1989.

Exellent critical edition with French translation, of Ptolemy's optical work, preserved only in medieval Latin translation made from an Arabic version. Cf. items 1222, 1223.

1144. Smith, A. Mark. *Ptolemy's Theory of Visual Perception.* Philadelphia: American Philosophical Society, 1996.

English translation of Ptolemy's *Optics* (item 1143). See review by E. Knobloch in **MR** 97g:01005.

Theodosios

1145. Paul Ver Eecke. *Les sphériques de Théodose de Tripoli.* Bruges: Desclée, De Brouwer et Cie., 1927.

A French translation of a first century B.C. source for the study of great circles and parallel circles on a sphere, although Theodosios was from Bithynia, not Tripoli.

Theon of Alexandria

1146. Rome, A., ed. *Commentaire sur les livres 1 et 2 de l'Almageste (commentaires de Pappus et de Théon d'Alexandrie sur l'Almageste, Tome 2).* Vatican City: Biblioteca Apostolica Vaticana, 1936.

Greek text of Theon of Alexandria's commentaries on Ptolemy's *Almageste*.

1147. Rome, A., ed. *Commentaire sur les livres 3 et 4 de l'Almageste (commentaires de Pappus et de Théon d'Alexandrie sur l'Almageste, Tome 3)* Vatican City: Biblioteca Apostolica Vaticana, 1943.

Greek text of Theon of Alexandria's commentaries on Ptolemy's *Almageste*. See also item 1137.

1148. Tihon, A., ed. *Le Petit Commentaire de Théon d'Alexandrie aux Tables Faciles de Ptolémée. Histoire du texte, édition critique, traduction.* Vatican City: Biblioteca Apostolica Vaticana, 1978.

Critical edition with French translation of Theon of Alexandria's Short Commentary to Ptolemy's *Easy Tables*, a work that explains how to use the table. See also item 1149.

1149. Mogenet, J., and A. Tihon, eds. *Le Grand Commentaire de Théon d'Alexandrie aux Tables Faciles de Ptolémée: Livre I. Histoire du texte, édition critique, traduction.* A. Tihon., ed. *Livres II et III. Édition critique, traduction, commentaire. Vatican City: Biblioteca Apostolica Vaticana, 1985, 1991.*

The first reliable critical edition, with French translation, for the existing first three books (the fourth is very incomplete, the fifth completely lost) of Theon of Alexandria's Great Commentary on Ptolemy's *Easy Tables*. Tihon's commentary helps the reader to understand Theon's difficult text. See also reviews by E. Knobloch in **MR** 87h:01007, and by R. Mercier in **MR** 93h:01007.

Theon of Smyrna

1150. Hiller, E. *Theonis Smyrnaei Philosophi Platonici expositio rerum mathematicarum ad legendum Platonem utilium.* Leipzig: Teubner, 1878.

A useful handbook, the extant manuscripts are divided into three parts (Theon of Smyrna seems to have had a greater plan): arithmetic, music and astronomy. Though little originality can be recognized, its value consists in citations of many earlier lost sources. The translations are not always reliable (the English translation especially requires caution). French translation: J. Dupuis, Paris, 1982. Reprinted Bruxelles: Culture et Civilisation, 1966. English translation: *Mathematics Useful for Understanding Plato.* Translated from the 1892 Greek/French edition of J. Dupuis by Robert Lawlor, and Deborah Lawlor, edited and annotated by Christos Toulis, and others, San Diego: Wizards Bookshelf, 1970.

General Histories of Greek Mathematics

1151. Aaboe, Asger. *Episodes from the Early History of Mathematics.* New York: Random House, 1964.

Lets Euclid, Archimedes, and Ptolemy speak for themselves (if only in paraphrase) to provide a good introduction to Greek mathematics for the reader who is unfamiliar with it.

1152. Artmann, Benno. *Euclid: the Creation of Mathematics.* New York: Springer-Verlag, 1999.

1153. Becker, Oscar. *Das mathematische Denken der Antike.* 2nd ed. Göttingen: Vandenhoeck & Ruprecht, 1966.

The bulk of this book is a presentation of a wide selection of pieces of ancient mathematics, chosen to illustrate important problems and methods from those of ancient Babylon and Egypt to Diophantos. The book contains a thorough discussion of Archytas's duplication of the cube and both the theory of homocentric spheres and the general proportion theory of Eudoxos. For a much longer discussion of Eudoxos's contributions, the reader should consult O. Becker's "Eudoxos-Studien, I–V", *Quellen and Studien zur Geschichte der Mathematik, Astronomie und Physik*, Abt. B2 (1933), 311–333, 369–388; 3, 236–244, 370–388, and 389–410, but the reader should be aware that there is considerable debate about some of Becker's conclusions.

1154. Cantor, Moritz B. *Vorlesungen über Geschichte der Mathematik.* Leipzig: Teubner, 1880–1908. Reprinted New York: Johnson Reprint Corporation, 1965. 4 vols.

The first volume of this work, concerned with the history of mathematics to the year 1200 A.D., is a useful first reference for the history of Greek mathematics although much of it is now outdated since, for example, Cantor wrote before Archimedes's treatise *The Method* was even known, and Heron is placed in the first century B.C. See also items 891, 1664, 1871.

1155. Heath, T. L. *A History of Greek Mathematics.* Oxford: Clarendon Press, 1921. 2 vols. Reprinted New York: Dover, 1981.

The only complete history of almost 2000 years of Greek mathematics available in English. Based on a careful study of primary and secondary sources it is especially useful as an introduction to a study of the mathematical texts themselves, but not for the Oriental background to Greek mathematics. Its use of the concept "geometrical algebra" has been recently attacked (see item 1164), but it is still a major point of departure for all serious historical studies of Greek mathematics.

1156. Herz-Fischler, R. *A Mathematical History of Division in Extreme and Mean Ratio.* Waterloo, Ont.: Wilfred Laurier University Press, 1987.

Interesting and important book on the early mathematical history of the "golden section". Review in **MR** 88k:01006 by C. G. Fraser.

1157. Klein, Jacob *Greek Mathematical Thought and the Origin of Algebra.* Cambridge, Mass.: MIT Press, 1968. Reprinted New York: Dover, 1992, xv + 360 pp. (Paperback edition.)

Traces the concept of "number," with strong emphasis on the philosophical aspects, from early Greek mathematics through the works of Diophantos, arguing that these represent the tradition of theoretical logistic. The second half of the book is concerned with post-Greek mathematics.

1158. Knorr, W. R. *The Ancient Tradition of Geometric Problems.* Boston: Birkhäuser, 1986. Reprinted New York: Dover, 1993.

Investigates the efforts and techniques of solving geometric problems, from those of Hippocrates of Chios, through the geometers in Plato's Academy, including Eudoxus, Euclid, Archimedes, and Apollonius, until commentators in late antiquity. The author makes an energetic and convincing protest against the prevailing view that the development of Greek geometry was guided by philosophical interests, and successfully shows that the interest for problem-solving is enough to explain the evolution of geometry in classical Greece. This book is obligatory for those interested in Greek geometry, though it does not replace all of Heath's book, item 1155.

1159. Knorr, W. R. *Textual Studies in Ancient and Medieval Geometry.* Boston: Birkhäuser, 1989.

Starting his career with the book (item 1182) which marked the culmination of the 20th century tradition of mathematical reconstruction of Greek mathematics, Knorr considerably changed his method of investigation, giving more and more emphasis to the accurate textual studies of all the available materials. This new approach, or the new tradition of research he founded, culminates in this book (after having produced item 1158), which should be an important part of a new general history of Greek mathematics that is yet to come. This immense book (more than 800 pages) in which the author treats cube duplication and angle trisection in Greek (part 1) and Arabic (part 2), and the textual tradition of Archimedes's *Dimension of the Circle* (Greek, Arabic and Latin), is no doubt intended for specialists. Still, a glance at its pages would be useful in forming an idea of what it is like to study the history of ancient mathematics.

1160. Fowler, D. H. "Wilbur Richard Knorr (1945–1997): An appreciation". *Historia Mathematica*, 25 (1998), 123–132.

Contains the complete bibliography of this great historian of Greek mathematics, whose works cover so vast a range that it is difficult to find a topic about which he had nothing to say.

1161. Netz, Reviel. *The Shaping of Deduction in Greek Mathematics*. Cambridge: Cambridge University Press, 1999.

What is common between Euclid's *Elements* and the *Odyssey*? This book examines the form and style of Greek mathematical texts, which, like Homer's epics, depend largely on "formulae". The author elucidates how mathematical deduction is formed and how the formulae work. It also contains accurate analysis of the relation between the text and the diagram, and elucidates the indispensable role played by diagrams. This is a very interesting and valuable study from a point of view that nobody had ever thought of before.

1162. Neugebauer, Otto. *The Exact Sciences in Antiquity*. 1st ed. Copenhagen: E. Munksgaard and Princeton: Princeton University Press, 1951; also Princeton, 1952. 2nd ed. Providence, R.I.: Brown University Press, 1957. Reprinted New York: Harper, 1962.

Deals with the origin and transmission of Hellenistic exact sciences, i.e., mathematics and mathematical astronomy, although only the last chapter and two appendices are specifically concerned with Greek mathematics. An important work whose value is increased by the copious bibliographic notes at the end of each chapter. See also item 911.

1163. Neugebauer, Otto. *A History of Ancient Mathematical Astronomy*. 3 parts. Berlin, Heidelberg, New York: Springer-Verlag, 1975.

Gives an account of the "numerical, geometrical and graphical methods devised to control the mechanism of the planetary system" from about the fifth century B.C. to the seventh A.D. The results of a lifetime of scholarship, this work will be a standard tool for scholars of the ancient exact sciences for years to come. See also item 1002.

1164. Szabó, Árpád. *The Beginnings of Greek Mathematics*. Dordrecht, Boston: D. Reidel, 1978.

Studies the appearance and use of certain key words in context to investigate early Greek mathematics. Makes a strong case for the dominant role of music in the early history of proportion theory and of Eleatic dialectic in the beginnings of rigorous mathematics. An appendix argues that the commonly used term "geometric algebra" is quite misleading. In this way, this book has thrown into controversy quite a few interpretations that seemed established. The answers proposed by the author are, however, often too audacious to be conclusive. As Bowen correctly concludes (*Historia Mathematica* 11, 343) it "raises more questions than the author is truly prepared to answer."

1165. Van der Waerden, Bartel Leendert. *Science Awakening, I.* 2nd ed. Leyden: Noordhoff International Publishers and New York: Oxford University Press, 1961.

Aims at showing how Babylonian mathematics was transformed by early Greek mathematicians and then brought by Theaetetos and Eudoxos to the state found in Euclid's *Elements*. Photographs and illustrations exhibit the interaction of ancient mathematics and culture. The considerable controversy surrounding many of the conclusions indicates the important place the work once occupied among modern studies of Greek mathematics.

Studies

Research Survey

1166. Berggren, J. L. "History of Greek Mathematics: A Survey of Recent Research". *Historia Mathematica* 11 (4) (1984), 394–410.

Surveys the literature from the period 1953–1983 on the history of ancient Greek mathematics; contains an extensive bibliography.

1167. Knorr, W. R. "New Readings in Greek Mathematics: Sources, Problems, Publications". *Impact of Science on Society* 159 (1990).

Exposition of the new research trend, of which Knorr himself is an important advocate, with research survey up to 1980s.

The Method of Analysis

1168. Hintikka, J., and U. Remes. *The Method of Analysis: Its Geometrical Origin and Its General Significance.* Dordrecht, Boston: Reidel, 1974.

The authors present a view of the method of analysis (as explained and practiced by Pappos) which contradicts that of Mahoney, item 1169, in several important points. They argue that analysis should be seen primarily as an analysis of geometrical figures involving a search for "concomitants" rather than "consequences." The book is a highly readable attempt to use the philosophy of mathematics to shed light on historical questions.

1169. Mahoney, Michael S. "Another Look at Greek Geometrical Analysis". *Archive for History of Exact Sciences* 5 (1968), 318–348.

Asserts that instead of being a single method Greek analysis was a growing corpus of techniques and theorems for the generation and solution of problems, such as, for example, the technique of "verging" constructions.

1170. Behboud, A. "Greek Geometrical Analysis". *Centaurus* 37 (1994), 52–86.

A very good exposition of how analysis was used in Greek geometry. Examines the use of analysis in some examples taken from Pappus's Collection. Shows that analysis is not an automatic process, and that synthesis is not simple reverse of analysis.

Ruler and Compass

1171. Steele, A. D. "Über di Rolle von Zirkel und Lineal in der griechischen Mathematik". *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik* 1936, Abt. B3 287–369.

Thoroughly examines the role of ruler and compass in Greek geometry and in the mathematical arguments of Plato and other philosophers. One of the very few articles devoted to this topic. Shows clearly that the alleged restriction of instruments to ruler and compass did not exist, though sometimes circle and straight line were thought to be fundamental in some sense. Unfortunately, the fact does not falsify the preconception. As late as 1986, Knorr (item 1158) had to cite this article to get rid of the myth of ruler and compass.

Construction as Existence Proof

1172. Zeuthen, H. G. "Die geometrische Construction als 'Existenzbeweis' in der antiken Mathematik". *Mathematische Annalen* 47 (1896), 222–228.

This work is the origin of the argument that the construction of a geometric object served as the proof of its existence.

1173. Knorr, W. R. "Construction as Existence Proof in Ancient Geometry". *Ancient Philosophy* 3 (1983), 125–148.

Challenges Zeuthen's thesis in item 1172, showing ancient arguments which do not seem to care about existence, such as those involving the fourth proportional in Euclid or pointwise construction of a curve by some authors, thus concludes that there were not one but many philosophies in antiquity.

Crisis

1174. Hasse, H., and H. Scholz. "Die Grundlagenkrisis der griechischen Mathematik". *Kantstudien* 33 (1928), 4-34.

Combines the alleged crisis of Greek mathematics caused by the discovery of incommensurability with Zeno's paradoxes, assuming that the Pythagoreans tried to circumvent the difficulty by contriving infinitesimal magnitudes, which would have been the target of Zeno's critics. This ingenious but highly speculative argument, which was once popular, has turned out to involve too much chronological difficulties to be seriously considered.

1175. Freudenthal, H. "Y avait-il une crise des fondements des mathématiques dans l'antiquité?" *Bulletin de la société mathématique de Belgique* 18 (1966), 43–55.

Convincingly argues against the thesis of foundation crisis in Greek mathematics, allegedly caused by the discovery of incommensurability or by Zeno's critiques.

1176. Fowler, D. H. "The Story of the Discovery of Incommensurability, Revisited". In *Trends in the Historiography of Science*. Edited by Kostas Gravroglu, Jean Christianidis, and Efthymios Nicolaïdis. Dordrecht: Kluwer Academic Publishers, 1994, 221–235.

After a reexamination of the common stories about the discovery of incommensurability, argues that it may even have been an incidental event in pre-Euclidean mathematics.

Origins

1177. Dicks, D. R. "Thales". *Classical Quarterly* (New Series) 9 (1959), 294–309.

Shows that there is no ground to attribute to Thales the foundation of theoretical mathematics. Eudemus's testimony shoud be viewd as logical reconstruction of Thales's mathematical knowledge based on the tradition of his practical ability.

1178. Vitrac, B. "Mythes (et réalités?) dans l'histoire des mathématiques grecques anciennes". In *L'Europe mathématique*. (†Mathematical Europe†). Edited by C. Goldstein, J. Gray, and J. Ritter. Paris: 'Editions de la Maison des sciences de l'homme, 1996, 15–32.

Critically re-examines Eudemus's "Summary" in Proclus's Commentary on the First Book of Euclid's *Elements*, and convincingly suggests that its description of early developments of Greek mathematics is a result of rationalization on the part of Eudemus.

1179. Burkert, Walter. *Lore and Science in Ancient Pythagoreanism.* Cambridge, Mass.: Harvard University Press, 1972.

This is the most important and influential study on Pythagoras and Pythagoreanism in the 20th century. Its implication for the history of Greek mathematics is not yet fully appreciated and digested. The shamanic aspect of Pythagoras is emphasized, and his image as first philosopher or mathematician is greatly damaged, by critical examination of the documents. After this book, it is by far more difficult to attribute to Pythagoras or his direct disciples the creation of "Greek" mathematics—mathematics with rigorous demonstrations—except for contributions of Pythagoreans (not necessarily Pythagoras himself) to music theory. Chapter 6, titled "Pythagorean Number Theory", treats the alleged foundation of Greek mathematics by Pythagoreans.

1180. Huffman, Carl A. *Philolaus of Croton, Pythagorean and Persocratic.* Cambridge: Cambridge University Press, 1993.

Examines all the fragments (commentated on and translated by the author) attributed to Philolaus of Croton, contemporary of Socrates, the most prominent Pythagorean of the time, whose importance is highlighted especially after Burkert's study (item 1179). Based on the fragments judged as genuine, the author proposes an image of a natural philosopher, a serious thinker of the epistemology of mathematics. No contribution to mathematics is attributed to Philolaus, who is supposed to have applied mathematical ideas to philosophical problems. Though the interpretation and evaluation of Philolaus remains still subject to discussion, this book is an obligatory reference for any argument on the relation of Pythagoreanism and mathematics in 5th century.

1181. Zhmud', L. *Wissenschaft, Philosophie und Religion im frühen Pythagoreismus.* Akademie Verlag, 1997.

Strongly opposes the prevailing thesis of Burkert (item 1179), denying Pythagoras's shamanism, and defending the image of Pythagoras as founder of the scientific school.

Up to Euclid

1182. Knorr, Wilbur R. *The Evolution of the Euclidean Elements: A Study of the Theory of Incommensurable Magnitudes and Its Significance for Early Greek Geometry.* Dordrecht: Reidel, 1975.

An influential book which aims to give a new account of the pre-Euclidean development in the field of incommensurable magnitudes. Among many other things the book contains a critical examination of all previous reconstructions of proofs by Theodoros which led to difficulties in proving the side of a square measuring 17 feet is incommensurable with its diagonal and describes his own new one, giving a full examination of the nature of the new approach by Theaetetos that resolved the problem. Argues Books II, IV, X, and XIII of Euclid's *Elements* stem from Theodoros, Theaetetos, and Eudoxos while Books I, III, and VI are older, going back to Hippocrates of Chios.

1183. Fowler, D. H. *The Mathematics of Plato's Academy: A New Reconstruction.* Oxford: Oxford University Press, 1987. Paperback edition with corrections, 1990. Expanded second edition, 1999.

A highly developed exploration of the possibility that anthyphairesis may have been used to define not proportion a:b::c:d (cf. item 1153), but ratio a:b, and how substantial parts of Euclid's *Elements* and other texts may have had their origin in investigating, hypothesing, proving, exploiting, and extending its many useful and sometimes surprising properties. An unexpected feature of the book is a substantial mathematico-historical essay on continued fractions. What distinguishes this work from many other reconstructions is the exhaustiveness of its research, and its clear distinction between reconstruction and evidence. From the most strict and austere point of view, it may be seen as no more than a very good historical romance (accompanied with valuable source materials), but one should remember that very often a well-written romance is of great help to our understanding of the past.

1184. Mueller, I. *Philosophy and Deductive Structure in Euclid's Elements.* Cambridge, Mass.: MIT Press, 1981.

Although the book is, in a sense, a survey of *The Elements*, Mueller is principally concerned to illustrate some aspects of Euclid's conception of mathematics by an examination of the logical structure of Euclid's chief work. Thus, a key feature of the study of a single proposition, a group of propositions, or even of a whole book is the study of how it is used elsewhere in *The Elements*. Along with the studies of Beckmann (item 1186), and Neuenschwander (items 1187, 1188), this book has established a new approach to Greek mathematical texts, and is one of the most frequently referred to works.

1185. Mueller, I. "On the Notion of a Mathematical Starting Point in Plato, Aristotle, and Euclid". In *Science and Philosophy in Classical Greece.* Edited by A. C. Bowen New York: Garland, 1991.

Investigates the concept of definitions, postulates and common notions (axioms) found in Plato, Aristotle, and Euclid, and concludes that Plato used only definitions, and that postulates and common notions are introduced later.

1186. Beckmann, F. "Neue Gesichtspunkte zum 5. Buch Euklids". *Archive for History of Exact Sciences* 4 (1/2) (1967), 1–144.

Examines closely the logical structure of Euclid's Book 5 from the standpoint of modern mathematics and argues that it is not "ratio" but magnitudes, and their relation of "having a ratio", which are fundamental in the theory of that book. Contains an extensive bibliography.

1187. Neuenschwander, E. "Die ersten vier Bücher der Elemente Euklids". *Archive for History of Exact Sciences* 9 (1972–73), 325–380.

Analysis of the logical structure and research of the historical evolution of the first four books of Euclid's *Elements*, accompanied with a very useful table of the cross-reference of propositions; the references are classified into three groups from most literally explicit to implicit ones.

1188. Neuenschwander, E. "Die stereometrischen Bücher der Elemente Euklids". *Archive for History of Exact Sciences* 14 (1974), 91–125.

Similar and no less useful analysis with tables and schemes as (item 1187) for Books 11 to 13 of Euclid's *Elements*.

1189. Saito, K. "Compounded Ratio in Euclid and Apollonius". *Historia Scientiarum* No. 31 (1986), 25–59.

Deals with the use (and non-use) of the "compounded ratio" in the works of Euclid, Apollonius, and Pappus. This term appears in Euclid's *Elements* only twice, and there are some propositions in which the notion of compounded ratio could possibly have been used, but was substituted by another technique based on simpler theorems of proportions. Thus the author emphasizes the non-algebraic character of the Greek theory of proportions.

1190. Grattan-Guinness, I. "Numbers, Magnitudes, Ratios, and Proportions in Euclid's *Elements*: How Did He Handle Them?" *Historia Mathematica* 23 (1996), 355–375.

Gives a neat sketch of Euclid's treatment of numbers, geometric magnitudes, and ratios and proportions, re-examining the 1970s polemics concerning algebraic interpretation.

1191. Knorr, W. R. "The Wrong Text of Euclid: On Heiberg's Text and its Alternatives". *Centaurus* 38 (1996), 208–276.

Casts a reasonable doubt on the authenticity of Heiberg's Greek edition of Euclid, by a minute examination of Book XII of the *Elements*. Knorr compares Heiberg's edition, which was based mainly on codex P, with another Greek codex b, which is considerably different from other Greek traditions, and with medieval Latin translations made from Arabic, and persuasively argues that the codex that is the basis of Heiberg's edition has probably suffered modifications, while Arabic-Latin tradition preserves a more faithful form to the original.

1192. Taisbak, Ch. M. "Elements of Euclid's *Data*". *Peri ton mathematon*. Edited by I. Mueller. Alberta: Academic Printing & Publishing, 1991. 135–171.

A very good examination of the terminology and contents of the *Data*, an unduly neglected work of Euclid.

1193. Taisbak, Ch. M. *Division and logos: A Theory of Equivalent Couples and Sets of Integers Propounded by Euclid in the Arithmetical Books of the Elements*. Odense: Odense University Press, 1971.

A very detailed logical analysis of the Arithmetical Books (Books 7–9, mostly book 7) of *The Elements*. Importation of modern ideas and interpretations are carefully avoided, and Euclid's line of thought is traced as faithfully as possible.

Archimedes

See also item 1100.

1194. Knorr, Wilbur R. "Archimedes and *The Elements*: Proposal for a Revised Chronological Ordering of the Archimedean Corpus". *Archive for History of Exact Sciences* 19 (1978), 211–290.

The pivot of a series of studies of Archimedes's work by the same author, this paper takes issue with the usually accepted ordering and argues on the basis of language and techniques for a quite different sequence and a developmental view of the Archimedean corpus into "early" and "late" works. Uses re-ordering to conclude that mechanical works were less important in Archimedes's development than others have thought.

1195. Knorr, Wilbur R. "Archimedes and the Measurement of the Circle: A New Interpretation". *Archive for History of Exact Sciences* 15 (2) (1976), 115–140.

This is part of an extensive literature on the bounds for the ratio of the circumference to the diameter of a circle which Heron reports he found in a treatise of Archimedes. The author presents his version of these bounds and how Archimedes may have arrived at them.

1196. Schneider, Ivo. *Archimedes: Ingenieur, Naturwissenschaftler und Mathematiker*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1979.

Contributes an account of the past century of research on Archimedes's life and works, with an emphasis on recent studies, in which Schneider argues for the importance of Archimedes's early mechanical investigations in his intellectual development. The 19-page bibliography is virtually exhaustive.

1197. Sato, T. "A reconstruction of *The Method* 17, and the Development of Archimedes' Thought on quadrature — Why did Archimedes not notice the internal connection in the problems dealt with in many of his works?" *Historia Scientiarum* part 1: 31 (1986), 61–86; part 2: 32 (1987), 75–142.

Part 1 deals with the chronology of Archimedes's works, proposing an alternative view to Knorr's (item 1194). Part 2 analyses Archimedes's quadrature methods in several of his works, which have internal logical connections that seem to have escaped the author himself.

1198. Berggren, J. L. "Spurious Theorems in Archimedes' *Equilibrium of Planes: Book I*". *Archive for History of Exact Sciences* 16 (1976), 87–103.

Argues, on the basis of an analysis of the logical structure of *Equilibrium of Planes: Book I*, that five, and possibly seven, theorems in this work are not due to Archimedes but to later editors.

Apollonius

1199. Zeuthen, H. G. *Die Lehre von den Kegelschnitten im Altertum.* Kopenhagen, 1986. Reprinted Hildesheim: Olms, 1966

Still the only comprehensive study of the *Conics* of Apollonius, and is the obligatory reference point for any research on the topic, though the author's strong inclination to algebraic interpretation needs careful examination.

Late Antiquity

1200. Barnes, T. D., ed. *The Sciences in Greco-Roman Society.* Edmonton, Alberta: Academic Printing and Publishing, 1994.

It contains five papers delivered at a colloquium held in April 1994 at University of Toronto; is one of few books about science in Roman Period. As for history of mathematics, it contains: A. Jones, "The Place of Astronomy in Roman Egypt"; A. Barker, "Greek Musicologists in the Roman Empire"; and D. Pingree, "The Teaching of the *Almagest* in Late Antiquity".

1201. Cuomo, S. *Pappus of Alexandria and the Mathematics of Late Antiquity* Cambridge: Cambridge University Press, 1999.

1202. O'Meara, D. *Pythagoras Revived: Mathematics and Philosophy in Late Antiquity.* Oxford: Clarendon Press, 1989.

Traces the development of philosophy of mathematics in neoplatonic and neopythagorean philosophers, to whom we owe a large part of our knowledge of the history earlier mathematics. Beginning with neopythagoreans such as Numenius and Nicomachus, the book naturally ends with Proclus, to whom nearly one third of the book is dedicated. Extensively examined also is Iamblichus's work of nine (or ten) books: *On Pythagoreanism*, providing Psellus's excerpts for three of the lost books of this work.

Astronomy (Including Spherics and Trigonometry)

Influence of Babylonian Astronomy

1203. Jones, A. "The adaptation of Babylonian Methods in Greek Numerical Astronomy". *Isis* 82 (1991), 441-453.

Re-examines the assumed contrast between the arithmetical astronomy of the Babylonians and of astrologers and the numerical-geometrical astronomy founded by Hipparchus and completed by Ptolemy. Hipparchus did not hesitate to make use of Babylonian arithmetical schemes, for initial data, and thus his work is a strange mixture of the two methods, while the *Almagest* is planned to be a result of logical deduction.

1204. Jones, A. "On Babylonian Astronomy and Its Greek Metamorphoses". In *Tradition, Transmission, Transformation*. Edited by F. J. Ragep, S. Ragep, et al. Leiden: Brill, 1996, 139–155.

Presents the transmission of astronomy from Babylonia to Greece that took place (presumably) in the last centuries B.C., as an example of transmission of a culture. The author skillfully points out, with very few recourses to technical terms and technical details, that the same data should have changed in its meaning as a result of its adaptation into the geometric model that was growing in Greek astronomy.

Before Ptolemy

See also introductory essay in item 1121.

1205. Riddell, R. C. "Eudoxan Mathematics and the Eudoxan Spheres". *Archive for History of Exact Sciences* 20 (1) (1979), 1–19.

Demonstrates that three discoveries credited to Eudoxos may be extracted from the basic kinematic element in Eudoxos's model of homocentric spheres for the movement of the planets, the sun, and the moon.

1206. Yasukatsu Maeyama. "Ancient Stellar Observations: Timocharis, Aristyllus, Hipparchus, Ptolemy: the Dates and Accuracies". *Centaurus* 27 (1984), 280-310.

See review by K. P. Moesgaard, in **MR** 86h:01012.

1207. Neugebauer, Otto. "The Equivalence of Eccentric and Epicyclic Motion According to Apollonius". *Scripta Mathematica* 24 (1959), 5–21.

Presents an account of two sections in *The Almagest* that give a method of transforming an epicyclic model into an eccentric model and vice versa. The purpose is to argue that both selections are based on the work of Apollonios, whom Neugebauer regards as the real originator of Greek mathematical astronomy.

1208. Toomer, G. J. "The Chord Table of Hipparchus and the Early History of Greek Trigonometry". *Centaurus* 18 (1973), 6–28.

Shows how Hipparchus could have constructed his chord table (based on steps of 7-1/2°) using only theorems known very early in Greek mathematics and argues against any important role for Archimedes in the early history of trigonometry. (See also review by N. Swerdlow, *Mathematical Reviews* 58 (6) [December 1979], **MR** #26714.)

1209. Vogt, H. "Versuch einer Wiederherstellung von Hipparchs Fixsternverzeichnis". *Astronomische Nachrichten* 224 (1925), 17–54.

First serious study of Greek star catalogues, based on Hipparchus (item 1128).

Ptolemy

1210. Hamilton, N. T., N. M. Swerdlow, and G. J. Toomer "The Canobic Inscription: Ptolemy's Earliest Work". In *From Ancient Omens to Statistical Mechanics; Essays on the Exact Sciences Presented to Asger Aaboe*. Edited by J. L. Berggren, and B. R. Goldstein. Copenhagen: University Library, 1987, 55–73.

See review by A. Tihon, in **MR** 89m:01008.

1211. Pedersen, Olaf. *A Survey of the Almagest*. Odense: Odense Universitetsforlag, 1974.

A fine introduction to the study of Ptolemy's greatest work, *The Almagest* emphasizing the mathematical techniques employed by Ptolemy in building his geometrical models out of observational data. See, however, the review by G. Toomer, *Archives Internationales d'histoire des sciences* 100 (1977), 137–150, for corrections to some points in Pederson's work.

1212. Newton, R. R. *The Crime of Claudius Ptolemy*. Baltimore: The Johns Hopkins University Press, 1977.

A highly controversial and provocative criticism to Ptolemy's methods.

1213. Britton, J. P. *Models and Precision: The Quality of Ptolemy's Observations and Parameters*. New York: Garland, 1992.

See review by R. Nadal, *Mathematical Review*, **MR** 93m:01009.

1214. van Dalen, B. "On Ptolemy's Table for the Equation of Time". *Centaurus* 37 (1994), 97–153.

The author uses modern mathematical methods to recover the parameter values underlying the table for the equation of time in Ptolemy's Handy Tables and proposes a precise method by which that table was computed. This is a remarkable new approach. He compares the results with the information given by Theon of Alexandria in his commentaries on Ptolemy's works.

1215. Luckey, P. "Das Analemma von Ptolemäus". *Astronomische Nachrichten* 230 No.5498 (1927), cols. 17–46.

A fundamental paper analyzing the nomographics procedures Ptolemy describes in *On the Analemma* for solving some problems of spherical astronomy.

1216. Grasshoff, G. *The History of Ptolemy's Star Catalogue*. New York etc.: Springer, 1990.

See review by B. van Dalen in **MR** 91j:01008.

1217. Swerdlow, N. M. "The Enigma of Ptolemy's Catalogue of Stars". *Journal for the History of Astronomy* 23 (1992), 173–183.

See review by R. Nadal in **MR** 93g:01012.

1218. Pedersen, Olaf. "Logistics and the Theory of Functions: An Essay in the History of Greek Mathematics". *Archives Internationales d'Histoire des Sciences* 24 No. 94 (1974), 29–50.

Contends that the numerical procedures taken for granted in *The Almagest* constitute a theory of functions of one or more variables which was known to astronomers however much Greek mathematicians may have ignored it.

Astronomy in Late Antiquity

See item 1200.

Music Theory

See also items 1095, 1200.

1219. West, M. L. *Ancient Greek Music*. Oxford: Clarendon Press, 1992.

A good introduction to Greek music, concerned more with practice than theory, thus helps the reading of Vol. 1 of item 1095.

1220. Bowen, A. C. "Euclid's Sectio canonis and the History of Pythagoreanism". In *Science and Philosophy in Classical Greece*. Edited by A. C. Bowen. New York: Garland, 1991, 164–187.

Attentively examines the preface of Euclid's *Sectio Canonis*, clarifies the relations among movement, sound, number and ratio, and raises a reasonable doubt to its attribution to the Pythagoreans. The question forms a part of a greater problem of the meaning the word "Pythagorean".

1221. Bowen, A. C., and W. R. Bowen. "The Translator as Interpreter: Euclid's Sectio Canonis and Ptolemy's Harmonica in the Latin Tradition". In *Music Discourse from Classical to Early Modern Times*. Edited by M. R. Maniates. Toronto: University of Toronto Press, 1997, 97–148.

Studies Boethius' s translations of passages from Euclid and Ptolemy, focusing on how (and why) the translations change the meaning of the originals.

Optics and Catoprics

See also 3608.

1222. Lejeune, A. *Euclide et Ptolémée: Deux stades de l'optique geométrique grecque*. Louvain, 1948.

1223. Lejeune, A. *Recherches sur la catoptrique grecque, d'après les sources antiques et mediévales.* Brussels, 1957.

Lejeune's works are still the standard study in ancient optics, though some of his conclusions are challenged by Knorr (see below, items 1224, and 1225).

1224. Knorr, W. R. "Archimedes and the Pseudo-Euclidean Catoptrics: Early Stages in the Ancient Geometric Theory of Mirrors". *Archives internationales d'histoire des sciences* 35 (1985), 28-105.

See review by H. L. L. Busard in **MR** 89g:01005.

1225. Knorr, Wilbur, R. "Pseudo-Euclidean Reflections in Ancient Optics: A Re-examination of Textual Issues Pertaining to the Euclidean Optica and Catoptrica". *Physis* 31 (1994), 1–45.

Takes issue with Heiberg and Lejeune concerning the problem of authenticity of Euclid's two treatises: *Optics* and *Catoptrics.* After a thorough examination of extant texts and previous studies, the author defends the authenticity of most parts of both works, and, between the two extant forms of the text of the *Optics*, makes different choice from Heiberg. The relation of later commentaries to the extant text is also discussed.

1226. Jones, Alexander. "Peripatetic and Euclidean Theories of the Visual Ray". *Physis* 31 (1994), 47–76.

Traces the evolution of a physical theory of vision compatible with Euclid's treatment of the visual ray in *Optics.* Contains also some examination of the two versions of Euclid's *Optics.*

Mechanics

See also item 1094

1227. Clagett, Marshall. *The Science of Mechanics in the Middle Ages.* Madison: University of Wisconsin Press, 1959.

Includes a study of ancient mechanics, based on a distinction between a dynamical and statical approach to the problems of equilibrium, as well as a translation of the Arabic treatise, ascribed to Euclid, *The Book on the Balance.* See also item 1729.

1228. Landels, J. G. *Engineering in the Ancient World.* London: Chatto and Windus, 1978.

Neatly describes Greek and Roman technology, covering various topics including power and energy sources, water supplies, water pumps, cranes and hoists, catapults, sea and land transport. The author not only examines the extant documents, but also tries to test or verify the testimonies, making use of the method of experimental archaeology. A relatively small part of the book is dedicated to theoretical knowledge and to the ancient authors.

1229. Schürmann, A. *Griechische Mechanik und antike Gesellschaft.* Wiesbaden: Steiner, 1991.

Very thorough, detailed analysis of archaeological and textual evidence about ancient machines and ancient attitudes to machines, draws very close connections between mechanics and political power. Focuses on Ptolemaic and Roman Empire.

MEDIEVAL MATHEMATICS

ISLAMIC MATHEMATICS

"Islamic mathematics" and "Arabic mathematics" are modern historical terms for the mathematical sciences in Islamic civilization from the beginning of Islam (A.D. 622) until the 17th century. Although most of the mathematicians in this period of Islamic civilization were Muslims, some prominent mathematicians had other religious backgrounds (Christian, Jewish, Zoroastrian). Arabic was the main scientific language but not necessarily the native language of a mathematician, who might have been Persian, Turkish, etc.

The Islamic mathematical tradition was a continuation of the traditions of ancient Greece, India and pre-Islamic Iran. Some texts from the medieval Islamic period are lost in Arabic but available in medieval Latin or Hebrew translations. Thus material relevant to Islamic mathematics can also be found in the sections on Greek, Indian, Hebrew and Latin mathematics in this bibliography.

Although the field of Islamic mathematics is still under-researched, the literature is already so extensive that only a small part can be listed in a bibliography of this size. The present selection focuses on recent literature on Islamic mathematics in Western languages. More literature in Western languages can easily be found in the bibliographical works 1237 and 1238. References to the literature on Islamic mathematics in other languages can be found in items 1238 for publications in Russian, Arabic, Turkish and Uzbek, 1237 for publications in Arabic and Turkish and 1242 for publications in Persian. Unfortunately, it is not easy to trace all publications in Eastern languages on a given subject.

This bibliography includes references to non-trivial applications of mathematics to other sciences in Islamic civilization. Examples are publications on the mathematical construction of the astrolabe, technical mathematical explanations of planetary models, optical problems leading to complicated geometrical problems, and so on. However, we have not included topics which are only indirectly related to mathematics, such as the theory of vision, star names, descriptions of the use of the astrolabe, and natural philosophy. This is not a bibliography on Islamic astronomy, optics, or instruments. Once a reference to an article or book has been found, it is often a major problem to find the article or book in question. A special section at the end of this bibliography lists collections of articles and reprinted works, containing articles on Islamic mathematics which are often difficult or impossible to find otherwise. The following journals specialize in Islamic science:

Al-Samt (Barcelona), *Arabic Sciences and Philosophy (Cambridge)* (http://www.cup.cam.ac.uk/Journals/JNLSCAT/asp/asp.html), *Journal for the History of Arabic Science (Aleppo)*, and *Zeitschrift für*

Geschichte der arabisch-islamischen Wissenschaften (Frankfurt). Articles on Islamic mathematics also appear in journals on the general history of mathematics or science, on Oriental studies, etc. The best sources of information on current research are the sections 01A30 of the *Mathematical Reviews* and the *Zentralblatt der Mathematik*, the Abstracts section in *Historia Mathematica* (http://www.chass.utoronto.ca/hm), and the *Isis Cumulative Bibliography*.

Introductory Works

Good introductions to the history of Islamic mathematics are found in:

1230. Berggren, J. L *Episodes in the Mathematics of Medieval Islam*. New York: Springer-Verlag, 1986.

This book concentrates on mathematics still used in high school, and on the Eastern part of the Islamic world. Written at college level, with exercises, and some bibliographical references.

1231. Yushkevich, Adolf P. *Geschichte der Mathematik im Mittelalter*. Leipzig: B. G. Teubner, 1964.

A German translation of the original Russian version of 1961. This book offers the most comprehensive (although outdated) account of achievements of the mathematicians of the Islamic world in the Middle Ages that is available to date. See also item 1232.

1232. Yushkevich, Adolf P. *Les mathématiques arabes (VII^{e}–XV^{e} siècles)*. Paris: J. Vrin, 1976.

French translation of the chapter in item 1231 dealing with Islamic mathematics.

1233. Samsó, Julio. *Las Ciencias de los Antiguos en al-Andalus*. Madrid: MAPFRE, 1992.

Survey of mathematics and astronomy in Islamic Spain.

1234. Kennedy, Edward S. "The Arabic Heritage in the Exact Sciences". *Al-Abhath* 23 (1970), 327–344.

Reprinted in item 1436. Brief introduction to mathematics, astronomy, mechanics, and physics in the medieval Islamic world.

1235. Sesiano, J. "Arabische Mathematik im 8.-10. Jahrhundert". In *Science in Western and Eastern Civilization in Carolingian Times*. Edited by P. L. Butzer, and D. Lohrmann. Basel: Birkhäuser, 1993, 399-442.

Introduction to the first two centuries of Islamic mathematics, with many specific mathematical examples.

1236. al-Biruni, Abu al-Rayḥān. *The Book of Instruction in the Elements of the Science of Astrology.* Translated by R. Ramsay Wright. London: Luzac & Co., 1934.

The following book is recommended as a first course in mathematics (and astronomy) written by a medieval Islamic mathematician himself.

Bibliographies and Handbooks

The two most important works are:

1237. Sezgin, Fuat. *Geschichte des arabischen Schrifttums.* Leiden: E. J. Brill, 1967–.

The fundamental work for the period up to about 1040 A.D. Volumes 5 (1974), 6 (1978), and 7 (1979) are respectively devoted to mathematics, astronomy, and astrology. Sezgin deals with authors writing in Arabic, and with Greek, Indian and Sassanid authors whose works were transmitted into Arabic. For every author Sezgin gives an introduction, all known medieval Arabic manuscripts, references to Arabic editions, medieval translations if any, modern translations if any, and studies (prior to 1974 or 1978). Volume 5 is reviewed in *Archives Internationales d'histoire des sciences* 28 (1978), 325–329.

1238. Rosenfeld, B. A., and G. P. Matvievskaya. *Matematiki i astronomi musulmanskogo srednevekovya i ikh trudi (VII–XVII vv).* Moscow: Nauk, 1983. 3 vols.

This work is organized in roughly the same way as item 1237. Rosenfeld and Matvievskaya deal with authors in the Islamic world until 1900. Since much of the information in this work consists of names and numbers, readers whose knowledge of Russian is limited to the letters of the Russian alphabet can consult this work with profit. A supplement volume and an English translation of the work are in preparation. There are plans to put an continuously updated English data base, similar to this work and to Sezgin's work, on the internet, available free of charge to all interested readers.

1239. Suter, Heinrich. "Die Mathematiker und Astronomen der Araber und ihre Werke". *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 10 (1900), ix + 278 pp. Reprinted Amsterdam: APA-Oriental Press, 1981. Also reprinted in item 1454. Additions and corrections in *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 14 (1902), 155–185, and by H. J. P. Renaud, *Isis* 18 (1932), 166–183.

This work is now superseded by the works of Sezgin (item 1237) and Rosenfeld-Matvievskaya (item 1238).

1240. *Encyclopaedia of Islam.* 2nd ed. Leiden: E. J. Brill, and London: Luzac and Company, 1960- .

A general encyclopedia, alphabetically arranged, with cross-references and indices. Contains (generally short) articles of varying quality on Islamic mathematicians and Arabic mathematical terms. The second edition is nearing completion.

1241. *Index Islamicus* founded by Pearson, J. D., ed. (1906-85); continued as *Quarterly Index Islamicus* (1986-93); continued as *Index Islamicus* (1996 -).

This review journal appears four times a year, with bibliographic entries on all aspects of Islamic civilization. There is a special section on Science (in the medieval Islamic world).

1242. Ghorbani, Abu-l-Qasim. *Biographie des mathématiciens de l'époque islamique de* 3^{e} *à* 11^{e} *siècle de l'hégire.* Tehran: Presses Universitaires de l'Iran, ca.1995, 543 pp. In Persian.

The most up-to-date work on Islamic mathematicians of Iranian descent (a substantial part of all Islamic mathematicians). 543 pages.

1243. Storey, C. A. *Persian Literature. A Bio-Bibliographical Survey.* London: Luzac and Co., 1927–1953.

Volume II, Part I, deals with mathematics and astronomy. Useful for readers who do not know Persian and cannot consult item 1242.

1244. Sánchez Pérez, José A. *Biografías de Matemáticos Árabes que florecieron en España.* Madrid: Estanislao Maestre, 1921.

Information on 191 mathematicians (and astronomers) in medieval Islamic Spain.

1245. Sezgin, F., ed. *Bibliographie der deutschsprachichen Arabistik und Islamkunde.* Vol. 5: *Wissenschaftsgeschichte.* Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1986.

Very complete survey of articles and reviews in German, with special sections on mathematics and astronomy.

1246. Endress, G. "Die Wissenschaftliche Literatur". In *Grundriss der Arabischen Philologie.* Vol 3: *Supplement.* Edited by W. Fischer. Wiesbaden: Ludwig Reichert Verlag, 1992, 1-152.

Scholarly introduction to Islamic philosophy, sciences and medicine, with many references.

1247. Nasr, Seyyed Hossein. *An Annotated Bibliography of Islamic Science.* Vol. 3: *Mathematics, Optics, Music, Astronomy, Astrology.* Tehran: Cultural Studies and Research Institute, 1991.

Bibliography of printed works in non-Islamic languages before 1970. Contains more than 1100 items on mathematics, astronomy and optics.

1248. Kennedy, E. S., and M.-H. Kennedy. *Geographical Coordinates of Localities from Islamic Sources*. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1987.

Sorting of thousands of geographical coordinates of cities from more than 70 medieval Arabic sources. Includes discussion of zero meridian and precision.

1249. Lamrabet, D. *Introduction à l'histoire des mathématiques maghrébines*. Rabat, 1994.

Information on more than 500 mathematicians in Islamic Spain and the Maghreb (modern Morocco, Algeria, Tunesia).

1250. Berggren, J. L. "History of Mathematics in the Islamic World: The Present State of the Art". *Middle East Studies Association Bulletin* 19 (1985), 9-33.

A selective review of the literature from 1970-1985, with 115 references.

1251. Berggren, J. L. "Mathematics and Her Sisters in Medieval Islam: A Selective Review of Work Done from 1985 to 1995". *Historia Mathematica* 24 (1997), 407-440.

As above (item 1250), with 182 references.

1252. Rashed, R. *Encyclopaedia of the History of Arabic Sciences*. London: Routledge, 1996.

Vol. 1: *Astronomy - Theoretical and Applied*, Vol. 2: *Mathematics and Physical Sciences*, Vol. 3: *Technology, Alchemy and Life Sciences*. Not an encyclopaedia, but a collection of articles by different authors on various topics in the history of science in Islamic civilization. Most articles are syntheses of the research done by its author. The articles on applied mathematics are especially useful. See items 1387, 1408, 1427.

1253. Ibn al-Nadīm. *Fihrist*. Translated by B. Dodge. New York: Columbia University Press, 1970.

An example of a medieval bibliography, containing a large chapter on mathematics and astronomy. Originally a bookseller's list from the 10th century and later extended, this is one of the standard Arabic bibliographical sources for the history of Arabic science.

1254. Brentjes, S. "Historiographie der Mathematik im islamischen Mittelalter". *Archives Internationales d'Histoire des Sciences* 42 (1995), 27-63.

Discusses texts by medieval Islamic authors (such as item 1253) dealing with the history of mathematics.

Illustrated Works

1255. King, D. *A Survey of the Scientific Manuscripts in the Egyptian National Library*. (American Research Center in Egypt.) Catalogs, Vol. 5. Winona Lake, Ind.: Eisenbrauns, 1986.

More than one hunderd beautiful black-and-white photographs of manuscripts.

1256. Nasr, S. H *Islamic Science, an Illustrated Survey.* London: World of Islam Festival Publishing Co., 1976.

The book contains many beautiful colour photos, but the text is unreliable, see the review by King, D., "Islamic Astronomy and Mathematics: An Essay Review", *Journal for the History of Astronomy* 9 (1978), 212–219; reprinted in *Bibliotheca Orientalia* 35 (1978), 339–343, and in item 1442.

1257. *El Legado Científico Andalusí.* Madrid: Museo Arqueológico Nacional, 1992.

Catalog of an exposition organized by J. Samso in 1992. With scholarly introductions in Spanish to various fields in medieval Islamic science, and very good colour photographs of manuscripts and scientific instruments.

1258. Necipoğlu, G. *The Topkapi Scroll—Geometry and Ornament in Islamic Architecture.* Santa Monica: Getty Center for the History of Art and the Humanities, 1995.

Superb colour reproductions of a 17th century scroll with complicated mosaic and muqarnas drawings in the Topkapi Library in Istanbul, with scholarly commentary, and an essay on the geometry of the muqarnas by Muhammad Asad.

Texts and Commentaries (Specific Authors)

What follows is a listing of the major edited texts currently available in good translations in Western languages, together with some introductory historical studies which focus on a single author. Because an alphabetic listing of Arabic names is somewhat problematic, the authors will be listed in chronological order. The major Greek authors whose works were translated into Arabic have been included in the list. The reader should be aware that many texts have been published in Arabic editions (without translation into a Western language) or in facsimile, and that some important texts are available only in Russian translations. References to these publications can be found in the bibliographies (see items 1237 and 1238).

Euclid

See also items 1286, 1342, 1385, 1457, Vols. 14-20.

1259. Klamroth, M. "Ueber den arabischen Euklid". *Zeitschrift der deutschen morgenländischen Gesellschaft* 35 (1881), 270–326, 788.

Still a basic work on the Arabic Euclid.

1260. Knorr, W. "The Wrong text of Euclid: On Heiberg's Text and Its Alternatives". *Centaurus* 38 (1996), 208-276.

Supports Klamroth's view that the Arabic manuscripts are important for the reconstruction of the original text of the *Elements* text, contrary to the opinion of Heiberg.

1261. de Young, Gregg. "Isḥāq ibn Ḥunayn, Ḥunayn ibn Isḥāq, and the Third Arabic Translation of Euclid's *Elements*". *Historia Mathematica* 19 (1992), 188-199

A clear introduction to the very complex transmission of Euclid's *Elements* into Arabic.

1262. Sabra, A. I. "Simplicius's Proof of Euclid's Parallel Postulate". *Journal of the Warburg and Courtauld Institutes* 32 (1969), 1-24.

Reprinted in item 1449. Discussion of a "proof" of the parallel postulate by the Greek philosopher Simplicius (sixth century A.D.) which survives in Arabic texts.

Archimedes

See also items 1278, 1401, 1403.

1263. Lorch, R. "The Arabic transmission of Archimedes' Sphere and Cylinder and Eutocius' Commentary". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 5 (1989), 94-114.

Reprinted in item 1445.

Apollonios

1264. Toomer, G. J. *Apollonius Conics, Books V-VII. The Arabic Translation of the Lost Greek Original in the Version of the Banū Mūsā.* New York: Springer Verlag, 1990. 2 vols.

Edition of the Arabic text of the lost Books V-VII of the *Conics* with English translation, commentary and glossaries.

1265. Hogendijk, J. "Arabic Traces of Lost Works of Apollonius". *Archive for History of Exact Sciences* 35 (1986), 187-253.

Presents fragments of the *Plane Loci*, the *Tangencies* and the *Neuseis*.

1266. Hogendijk, J. *Ibn al-Haytham's Completion of the Conics.* New York: Springer Verlag, 1985.

Arabic text and English translation of the reconstruction of the lost Book VIII of the *Conics* of Apollonius by Ibn al-Haytham.

Diocles

1267. Diocles. *On Burning Mirrors.* The Arabic translation of the lost Greek original, edited, with English translation and commentary, by

G. J. Toomer. (Sources in the History of Mathematics and Physical Sciences, 1.) New York: Springer-Verlag, 1976.

Diophantos

1268. Sesiano, J., ed. *Books IV to VII of Diophantus' "Arithmetica" in the Arabic Translation Attributed to Qustā ibn Lūqā.* Edited by J. Sesiano. Berlin, Heidelberg, New York: Springer-Verlag, 1982.

Edition with English translation of the four books of the *Arithmetica* of Diophantos, which are lost in Greek but which were discovered in 1968 by F. Sezgin in an Arabic manuscript in Meshed in Iran.

1269. Diophante. *Les Arithmétiques, texte établi et traduit par R. Rashed.* Paris: Les Belles Lettres, 1984. 2 vols.

Edition with French translation of the four Arabic books of the *Arithmetica* of Diophantos (based on the same manuscript as item 1268). On the publication history of this Arabic manuscript, see the review of item 1268 in *Historia Mathematica* 12 (1985), 82-85; the review of item 1269 in *Annals of Science* 44 (1987), 308-311; and the account in *Revue des Questions Scientifiques* 156 (1985), 237-241.

Menelaos of Alexandria

1270. Krause, M. *Die Sphärik von Menelaos aus Alexandrien in der Verbesserung von Abu Naṣr Manṣūr b. ʿAlī b. ʿIraq. Mit Untersuchungen zur Geschichte des Textes bei den islamischen Mathematikern. Abhandlungen der Geschichte der Wissenschaften zu Göttingen philol.-hist. Klasse*, dritte Folge 17 (1936).

Edition with German translation of an Arabic revision of the lost Greek original of the *Spherics* of Menelaos of Alexandria.

Pappos

1271. Thomson, W., ed. *The Commentary of Pappus on Book X of Euclid's Elements.* Cambridge, Mass.: Harvard Semitic Series # 8, 1930.

Arabic text and translation with commentary of a treatise on irrational magnitudes. The Greek original is lost. Reprinted in item 1457, Vol.16.

Al-Khwārizmī

See also item 1457, Vols. 1-6.

1272. Rosen, F., ed. *The Algebra of Mohammed ben Musa (al-Khwārizmī).* London: Oriental Translation Fund, 1831. Reprinted Hildesheim: Olms, 1986.

Arabic text of the *Algebra* of al-Khwārizmī, with English translation. Various medieval Latin translations of the *Algebra* of al-Khwārizmīhave also been published.

1273. Folkerts, M. *Die älteste lateinische Schrift über das indische Rechnen nach al-Khwārizmī. Edition, Übersetzung und Kommentar.* München: Bayerische Akademie der Wissenschaften, 1997.

This is a new edition of the complete medieval Latin translation of the *Arithmetic* of al-Khwārizmī (previous editions are all incomplete). This work is lost in Arabic.

1274. Al-Khwārizmī, Muḥammad b. Mūsā. "The Astronomical Tables of al-Khwārizmī". Translated by O. Neugebauer. *Kongelige Danske Videnskabernes Selskab, hist.-filos. Skrifter* (Copenhagen), 4 (1962).

Based on the medieval Latin translation by Adelard of Bath. The Arabic original is lost. See the review by G. J. Toomer in *Centaurus* 10 (1964), 202-212.

1275. King, D. A "Al-Khwārizmī and New Trends in Mathematical Astronomy in the Ninth Century". Vol 2. (Occasional Papers on the Near East.) New York University: Hagop Kevorkian Center for Near Eastern Studies, 1983.

Description and analysis of seven recently discovered minor works related to al-Khwārizmī.

1276. Van Dalen, B. "Al-Khwārizmī's Astronomical Tables Revisited: Analysis of the Equation of Time".

Published in item 1438, pp. 195-252. With survey of all work done on the tables of al-Khwārizmī.

Ibn Turk

1277. *Logical Necessities and Mixed Equations by ʿAbd al-Hamīd ibn Turk and the Algebra of this Time.* Edited and translated by Sayili, A.. Ankara, 1962.

Al-Kindī

1278. Rashed, R., "Al-Kindī's Commentary on Archimedes' 'The Measurement of the Circle'". *Arabic Sciences and Philosophy* 3 (1993), 7-53.

Arabic text and English translation.

Banū Mūsa

See also item 1287.

1279. Clagett, M. *Archimedes in the Middle Ages.* Vol. 1. Madison: University of Wisconsin Press, 1964.

Includes an edition of the medieval Latin translation of the book on the *Measurement of Plane and Spherical Figures* by the Banū Mūsā (the three sons of Mūsā), with English translation.

Thābit ibn Qurra

See also items 1406 and 1457, Vols. 21, 22.

1280. Suter, H. "Über die Ausmessung der Parabel von Thābit ibn Ḳurra al-Ḥarrānī". *Sitzungsberichte der Physikalisch-Medizinischen Sozietät zu Erlangen* 48-49 (1916-17), 65-80.

German translation of a treatise on the measurement of the parabolic segment. Reprinted in item 1454.

1281. Thābit ibn Qurra. *Oeuvres astronomiques.* Edited by R. Morelon. Paris: Les Belles Lettres, 1987.

Edition with French translation of 7 works of Thābit on mathematical astronomy.

1282. Suter, H. "Die Abhandlungen Thābit b. Ḳurras und Abū Sahl al-Kūhī's über die Ausmessung der Paraboloide". *Sitzungsberichte der physikalisch-medizinischen Sozietät zu Erlangen* 48-49 (1916-17), 186-227.

German translation of two treatises on the measurement of the paraboloid. Reprinted in item 1454.

1283. Garbers, K. "Ein Werk Ṯhābit b. Qurra's über ebene Sonnenuhren". *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung A: Quellen* 4 (1936), 1-80.

Text and German translation of a theoretical treatise on sundials. For a commentary see item 1284. Reprinted in item 1457, Vol. 22.

1284. Luckey, P. "Ṯābit b. Qurra's Buch über die ebenen Sonenuhren". *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung B: Studien* 4 (1938), 95-148.

Commentary to item 1283. Reprinted in item 1457, Vol. 22.

1285. Luckey, P. "Ṯābit b. Qurra über den geometrischen Richtigkeitsnachweis der Auflösung der quadratischen Gleichungen". *Berichte über die Verhandlungen der Sächsischen Akademie der Wissenschaften zu Leipzig, Mathematisch-physische Klasse* 93 (1941), 93-114.

Translation of a treatise by Thābit on geometric proofs for solutions of quadratic equations in the way of al-Khwārizmī. Reprinted in item 1457, Vol. 22.

1286. Sabra, A. I. "Thābit ibn Qurra on Euclid's Parallel Postulate". *Journal of the Warburg and Courtauld Institutes* 31 (1968), 12-32.

Reprinted in item 1449.

1287. Rashed, R, ed. *Les mathématiques infinitésimales du IXe au Xie siècles.* Vol. 1. Fondateurs et commentateurs. London: Al-Furqān Islamic Heritage Foundation, 1996.

Includes Arabic texts and French translations of the treatises by Thābit ibn Qurra on the measurement of the parabola, the measurement of the paraboloid, and the sections of a cylinder; and of *The Book on the Measurement of Plane and Spherical Figures* of the Banū Mūsā, the treatise by Ibrāhīm ibn Sinān on the measurement of the parabola, a treatise on isoperimetry by Abū Jaʿfar al-Khāzin, two versions of a treatise by al-Kūhī on the measurement of the paraboloid, a Hebrew fragment of Ibn al-Samḥ on sections of the cylinder, and fragments of the *Istikmāl* of al-Mu'taman ibn Hūd on the measurement of the parabola and on isoperimetry. This book does not include the text of item 1299.

Al-Ḥāshimī, ʿAlīibn Sulayman

1288. Al-Ḥāshimī, ʿAlīibn Sulayman. *The Book of the Reasons Behind Astronomical Tables.* Translation by Faud I. Haddad and E. S. Kennedy, and commentary by David Pingree and E. S. E. S. Kennedy. Delmar N.Y.: Scholars' Facsimiles and Reprints, 1981.

Translation of an early text on mathematical procedures in astronomical handbooks.

Al-Battānī

1289. Al-Battānī, Muḥammad b. Jābir. *Opus astronomicum.* Edited by C. A. Nallino. Milan: Osservatorio astronomico di Breva, 1899–1907. Reprinted Frankfurt: Minerva, 1969, and New York: Minerva, 1976.

The Arabic text of Al-Battānī's *zīj* (†Astronomical Handbook†) with modern Latin (sic) translation, introduction, and commentary (also in Latin). A fundamental work.

Abū Kāmil

See also item 1457, Vol. 23.

1290. Weinberg, J. *Die Algebra des Abū Kāmil.* München: Druck des Salesianischen Offizin, 1935.

Translation of the first part of the *Algebra*, based on the Hebrew and Latin versions.

1291. Levey, M. *The Algebra of Abū Kāmil, Kitāb fī'l-jabr wa'l-muqābala in a Commentary by Mordecai Finzi.* Hebrew Text, Translation and Commentary with Special Reference to the Arabic Text. Madison-Milwaukee, and London, 1966.

The translation is based on the Hebrew version of the text of Abu Kamil (not a commentary) by Mordechai Finzi. The Hebrew version does not always reflect the Arabic accurately. This is only the first part of Abū Kāmil's *Algebra*. For the second and third part see items 1292, 1293.

1292. Suter, H. "Die Abhandlung des Abū Kāmil Shoğāʿ b. Aslam über das Fünfeck und Zehneck". *Bibliotheca Mathematica*, dritte Folge, 10 (1909–1910), 15–42.

German translation of Italian translation of Hebrew translation of the second part of the *Algebra* of Abū Kāmil.

1293. Sesiano, J. "Les methodes d'analyse indeterminée chez Abū Kāmil". *Centaurus* 21 (1977), 89–105.

On the third part of the *Algebra* of Abū Kāmil.

1294. Suter, H. "Das Buch der Seltenheiten der Rechenkunst von Abū Kāmil al-Miṣ rī". *Bibliotheca Mathematica*, dritte Folge, 11 (1910-11), 100-120.

German translation of a treatise on systems of indeterminate linear equations.

Ibrāhīm ibn Sinān

See also item 1287.

1295. Suter, H. "Abhandlung über die Ausmessung der Parabel von Ibrāhīm b. Sinān b. Thābit. Aus dem Arabischen übersetzt und kommentiert". *Vierteljahresschrift der naturforschenden Gesellschaft in Zürich* 63 (1918), 214-228.

German translation of a treatise on the measurement of the parabola. Reprinted in item 1454.

Al-Khāzin, Abū Jaʿfar

See also item 1287.

1296. Woepcke, F. "Traduction d'un fragment anonyme sur la formation des triangles rectangles en nombres entiers, et d'un traité sur le même sujet par Abou Dja'far Mohammad ben Alhoçain". *Atti dell'Accademia Pontificia dei Nuovi Lincei* 14 (1860-1), 211-227, 241-269, 301-324, 343-356.

French translations of various 10th century treatises on Pythagorean triples. Reprinted in 1453.

1297. Anbouba, A. "Un traité d'Abū Jaʿfar sur les triangles rectangles numériques". *Journal for the History of Arabic Science* 3 (1979), 134-178.

Arabic text with French translation. Establishes the identity of Abū Jaʿfar al-Khāzin with Abū Jaʿfar Muḥammad ibn al-Ḥusayn.

1298. Lorch, R. "Abū Jaʿfar al-Khāzin on Isoperimetry and the Archimedean Tradition". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 3 (1986), 150-229.

Text and translation with commentary of a treatise on isoperimetry which is part of al-Khāzin's Commentary on the *Almagest*. Reprinted in 1445.

Al-Karābīsī

1299. Bessel-Hagen, E., and O. Spiess. "Das Buch über die Ausmessung des Kreisringes des Aḥmad ibn ʿOmar al-Karābīsī". *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung B: Studien* 1 (1931), 502-540.

Edition and German translation of a treatise on the measurement of the torus, in which al-Karābīsī uses infinitesimal arguments (not the classical Greek methods of Eudoxus). See the comments by S. Gandz in *Quellen und Studien zur Geschichte der Mathematik, Astronomie und Physik, Abteilung B: Studien*, 2 (1932), 98-105.

Ikhwān al-Ṣafā'

The Ikhwān al-Ṣafā' ("brethren of purity") were probably a (mystical?) group in the city of Basra in Irak. The group authored a series of more than 50 letters on science, philosophy and theology. The first letter is on arithmetic and number theory, the second letter on geometry.

1300. Goldstein, B. "A Treatise on Number Theory from a Tenth-Century Arabic Source". *Centaurus* 10 (1964), 127-164.

English translation of the first letter of the series by Ikhwān al-Ṣafā'.

1301. Brentjes, S. "Die erste Risāla der Rasā'il Ihwān al-Ṣafā über elementare Zahlentheorie - ihr mathematischer Gehalt und ihre Beziehungen zu spätantiken arithmetischen Schriften". *Janus* 71 (1984), 181-274.

German translation of the first letter of the series by Ikhwān al-Ṣafā', with historical analysis.

Al-Uqlīdisī

1302. Al-Uqlīdisī. *The Arithmetic of al-Uqlīdisī.* Translated and annotated by A. S. Saidan. Dordrecht and Boston: Reidel, 1978.

Al-Uqlīdisīwas the first to use decimal fractions.

Al-Ṣaghānī, Abū Ḥāmid

1303. Lorch, R. "Al-Ṣaghānī's Treatise on Projecting the Sphere".

Printed in item 1437, pp. 237-252; reprinted in item 1445. A study of a treatise in which al-Ṣaghānīstudies central projection of a sphere on a plane from a point not on the sphere, and an astrolabe constructed in this way. Many curves on this astrolabe are conic sections.

Al-Kūhī, Abū Sahl Wayjan ibn Rustam

See also items 1282, 1287.

1304. Woepcke, F. "Trois traités arabes sur le compas parfait". *Notices et extraits des manuscrits de la Bibliothéque Impériale et autres bibliothèques* 22 (1874), 1-175.

Includes an edition and French translation of a treatise on the perfect compass (for drawing conic sections) by Al-Kūhī. Reprinted in item 1453.

1305. Berggren, J. L. "Al-Kūhī's 'Filling a Lacuna in Book II of Archimedes' in the Version of Naṣīr al-Dīn al-Ṭūsī". *Centaurus* 38 (1996), 140-207.

Edition and English translation of a treatise by al-Kūhī on the construction of a certain spherical segment by means of conic sections.

1306. Berggren, J. L. "The Correspondence of Abū Sahl al-Kūhī and Abū Isḥāq al-Ṣābī". *Journal for the History of Arabic Science* 7 (1983), 39-124.

Edition and translation of a 10th-century correspondence between two friends on (meta)mathematical matters.

1307. Berggren, J. L. "Abū Sahl al-Kūhī's Treatise on the Construction of the Astrolabe with Proof: Text, Translation and Commentary". *Physis* 31 (1994), 141-252.

1308. Hogendijk, J. "Al-Kūhī's Construction of an Equilateral Pentagon in a Given Square". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften.* 1 (1985), 100-144.

English translation of a text related to conic sections.

Abū al-Wafā'

1309. Suter, H. "Das Buch der geometrischen Konstruktionen des Abū'l-Wefā'". *Abhandlungen zur Geschichte der Naturwissenschaften und der Medizin.* 4 (1922), 94-109.

Translation of part of a treatise on geometrical constructions. Reprinted in item 1454.

1310. Carra de Vaux, B. "L'almageste d'Abû'l-Wéfa Albûzdjâni". *Journal Asiatique*, Series 8, vol. 19 (1892), 408–471.

Discusses Abu'l-Wafa's *Almagest*, a treatise on mathematical astronomy named after Ptolemy's famous work.

Abū Saʿd al-ʿAlā' ibn Sahl

1311. Rashed, R. *Géométrie et Dioptrique au Xe siècle: Ibn Sahl, al-Qūhīet Ibn al-Haytham.* Paris: Les Belles Lettres, 1993.

Arabic texts with French translations of all available works by Al-ʿAlā, with a work by al-Kūhī on the astrolabe (also published in item 1307), and a fragment of the *Optics* of Ibn al-Haytham. See also item 1312.

1312. Rashed, R. "A Pioneer in Anaclastics: Ibn Sahl on Burning Mirrors and Lenses". *Isis* 81 (1990), 464-491.

Argues that Ibn Sahl used Snell's law of refraction in his study of hyperbolic lenses.

Al-Sijzī, Aḥmad ibn Muḥammad

1313. Al-Sijzī, Aḥmad ibn Muḥammad. *Treatise on Geometrical Problem Solving.* Edited by M. Bagheri, and J. Hogendijk. Tehran: Fatemi Publications, 1996.

Arabic text with Persian and English translations of a treatise on problem solving strategies in geometry, which resembles G. Polya's *How to Solve It.*

Ibn Yūnus

See also item 1457, Vols. 24, 25.

1314. King, D. A. "Ibn Yūnus' 'Very Useful Tables' for Reckoning Time by the Sun". *Archive for History of Exact Sciences* 10 (1973), 342–394.

Study of a set of tables used in medieval Cairo. Reprinted in item 1442.

1315. King, D. A. "A Double-Argument Table for the Lunar Equation Attributed to Ibn Yūnus". *Centaurus* 18 (1974), 129-146.

Reprinted in item 1442. Computation of the position of the moon according to the sophisticated Ptolemaic theory.

Abū Naṣr ibn ʿIrāq

1316. Samsó Moya, J. *Estudios sobre Abū Naṣr b. ʿAlī b. ʿIrāq.* Madrid, Barcelona: Asociación para la Historia de la Ciencia Española, 1969.

Abū Naṣr was one of the astronomers credited with the sine-theorem in spherical trigonometry. This book is a study of his trigonometry and includes a Spanish translation of several of his works.

Kūshyār ibn Labbān

1317. Kūshyār ibn Labbān. *Principles of Hindu Reckoning.* Edited by M. Levey, and M. Petruck. Madison and Milwaukee: University of Wisconsin Press, 1965.

English translation and facsimile of an Arabic manuscript of a treatise on arithmetic, which also exists in a Hebrew version.

1318. Berggren, J. L. "Spherical Trigonometry in Kūshyār ibn Labbān's *Jāmi ʿZīj*". In item 1437, 15-33.

Al-Karajī

1319. Sesiano, J. "Le traitement des équations indeterminées dans le *Badīʿ fī'l-ḥisāb* d'Abū Bakr al-Karajī". *Archive for History of Exact Sciences* 17 (1977), 297–379.

On indeterminate equations in the work of al-Karajī.

1320. Woepcke, F. *Extrait du Fakhrī, traité d'algèbre par Abou Bekr précédé d'un mémoire sur l'algèbre indeterminée chez les Arabes.* Paris, 1853.

French translation plus a few extracts in Arabic. Most or all of these problems were taken from Diophantus's *Arithmetica*, see item 1268. Reprinted in item 1453, also separately: Hildesheim: Olms, 1982.

Ibn al-Haytham

See also item 1266.

1321. Suter, H. "Die Abhandlung über die Ausmessung des Paraboloides von el-Ḥasan b. el-Ḥasan b. el-Haitham". *Bibliotheca Mathematica, dritte Folge* 12 (1911-12), 289-332.

German translation with commentary of Ibn al-Haytham's treatise on the measurement of paraboloids of revolution. Reprinted in item 1454.

1322. Suter, H. "Die Kreisquadratur des Ibn al-Haiṯam". *Zeitschrift für Mathematik und Physik, historisch-litterarische Abteilung* 44 (1899), 33-47.

Arabic text and German translation of a treatise by Ibn al-Haytham on the quadrature of the circle. Reprinted in item 1454.

1323. Rashed, R. "Ibn al-Haytham et la mesure du paraboloïde". *Journal for the History of Arabic Science* 5 (1981), 262–291.

Arabic text with French translation of Ibn al-Haytham's treatise on the measurement of paraboloids of revolution.

1324. Rashed, R. "Ibn al-Haytham et les nombres parfaits". *Historia Mathematica* 16 (1989), 343-352.

Reprinted in item 1448. Argues that Ibn al-Haytham, in his treatise on analysis and synthesis, stated and tried to prove the theorem of Euler to the effect that every even perfect number is of the form given by Euclid. See for a different interpretation the review in *Mathematical Reviews* **MR** 91d:01002.

1325. Rebstock, U. "Der Muʿāmalāt-Traktat des Ibn al-Haytham". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 10 (1995-6), 61-121.

Edition with German translation of Ibn al-Haytham's treatise on practical arithmetic.

1326. Dallal, A. "Ibn al-Haytham's Universal Solution for Finding the Direction of the Qibla by Calculation". *Arabic Sciences and Philosophy* 5 (1995), 145-194.

Text and English translation of a treatise on finding the direction of Mecca.

1327. Sabra, A. I. *The Optics of Ibn al-Haytham. Books I-III: On Direct Vision*. London: The Warburg Institute, 1989. 2 vols.

English translation of a fundamental treatise on optics, with much mathematics. A small part of Book V has also been translated in item 1328.

1328. Sabra, A. I. "Ibn al-Haytham's Lemmas for Solving 'Alhazen's Problem'". *Archive for History of Exact Sciences* 26 (1982), 299-324.

English translation of part of Book V of Ibn al-Haytham's *Optics*. Reprinted in item 1449. See also items 1347 and 1400.

1329. Rashed, R. *Les mathématiques infinitésimales du IXe au Xie siècles*. Vol. 2: *Ibn al-Haytham*. London: Al-Furqān Islamic Heritage Foundation, 1993.

Includes Arabic texts and French translations of nine treatises by Ibn al-Haytham: on the quadrature of lunes (2), the quadrature of the circle, the measurement of the paraboloid, the measurement of the sphere, isoperimetry, and root extraction (2), and on proposition X:1 of Euclid's *Elements*.

Al-Bīrūnī

see also items 1236, 1457, Vols. 32-36.

1330. Kennedy, E. S. "Al-Bīrūnī's Masudic Canon". *Al-Abhath* 24 (1971), 59–81.

Reprinted in item 1436. A detailed listing of the contents of Al-Bīrūnī's most important astronomical treatise, *al-Qānūn al-Masʿūdī*. This work has not yet been translated into a Western language.

1331. Schoy, C. *Die trigonometrischen Lehren des persischen Astronomen Abū'l-Raiḥān Muḥ. ibn Aḥmad Al-Bīrūnī*. Hannover: Heinz Lafaire, 1927.

German translation of one chapter of *al-Qānūn al-Masʿūdī*. Reprinted in item 1455.

1332. Al-Bīrūnī, Muḥammad b. Aḥmad, Abū Raihān. *The Determination of the Coordinates of Positions for the Correction of Distances between Cities*. A translation from the Arabic of al-Bīrūnī's *Kitāb Taḥdīd*

Niḥāyāt al-Amākin Li-taṣḥīḥ Masāfāt al-Masākin by Jamil Ali. Beirut: The American University of Beirut, 1967.

Translation of an important medieval work on mathematical geography. There is also a commentary in item 1333.

1333. Kennedy, E. S. *A Commentary upon Bīrūnī's Kitāb taḥdid [nihāyāt] al-amākin, an 11th Century Treatise on Mathematical Geography.* Beirut: The American University of Beirut, 1973.

1334. Al-Bīrūnī, Muḥammad b. Aḥmad, Abū Raihān. *The Exhaustive Treatise on Shadows.* Translation and commentary by E. S. Kennedy. Aleppo: University of Aleppo, 1976. 2 vols.

The English translation of al-Bīrūnī's text on sundials (Volume I) and extensive commentaries (Volume II).

1335. Debarnot, M.-T. *al-Bīrūnī, Kitāb maqālīdʿilm al-hay'a (Les clefs de l'astronomie). La trigonométrie sphérique chez les Arabes de l'est à la fin du* X^{e} *siècle.* Damascus: Institut Français de Damas, 1985.

Arabic text and French translation of al-Bīrūnī's *Maqālīd* with commentary on the history of spherical trigonometry.

1336. Suter, H. "Das Buch der Auffindung der Sehnen im Kreise von Abū'l-Raiḥān Muḥ. al-Bīrūnī". *Bibliotheca Mathematica, dritte Folge* 11 (1910), 11-78.

Translation of Al-Bīrūnī's treatise on chords, dealing with trigonometry. Reprinted in item 1454.

1337. Berggren, J. L. "Al-Bīrūnī on Plane Maps of the Sphere". *Journal for History of Arabic Science* 6 (1982), 47-112.

Translation of Al-Bīrūnī's treatise *Maqāla fītasṭīḥ al-suwar wa-tabṭīkh al kuwar*, with facsimile of an Arabic manuscript. See also the translation of the preface of the same text in item 1338.

1338. Richter-Bernburg, L. "Al-Bīrūnī's Maqāla fītasṭīḥ al-suwar wa-tabṭīkh al kuwar: A Translation of the Preface with Notes and Commentary". *Journal for History of Arabic Science* 6 (1982), 113-122.

1339. M. Saffouri, and A Ifram, trans. *Al-Bīrūnī on Transits. A Study of an Arabic Treatise Entitled Tamhīd al-mustaqarr li-taḥ qīq ma ʿnā al-mamarr. Translated by M. Saffouri and A. Ifram. With a Commentary by E. S. Kennedy.* Beirut: American University, 1959.

The treatise deals with mathematical astronomy and astrology.

1340. Al-Bīrūnī. *In den Garten der Wissenschaft. Ausgewählte Texte ... übersetzt und erläutert von G. Strohmaier.* Leipzig: Verlag Philipp Reclam jun, 1988.

Anthology of 98 selected passages from the scientific work of al-Bīrūnī.

Ibn Muʿādh al-Jayyānī

1341. Villuendas, M. V. *La trigonometria en el siglo XI. Estudio de la obra de (Ibn Muʿādh) El Kitāb mayhūlāt.* Barcelona: Instituto de Historia de la Ciencia de la Real Academia de Buenas Letras, 1979.

Arabic text and Spanish translation, plus commentary of a treatise in which Ibn Muʿādh derives theorems for solving spherical triangles from Menelaos's theorem.

1342. Plooij, E. B. *Euclid's Conception of Ratio and his Definition of Proportional Magnitudes as Criticized by Arabian Commentators.* Rotterdam: W. J. van Hengel, 1950.

Includes English translation (and facsimile of the Arabic manuscript) of Ibn Muʿād's commentary to Book V of the *Elements* of Euclid. Reprinted in item 1457, Vol. 19.

Ibn al-Zarqālluh (Azarquiel, al-Zarqālī)

Items 1438 and 1450 contain various other papers on Ibn al-Zarqālluh.

1343. Millás Vallicrosa, J. *Estudios sobre Azarquiel.* Madrid: Escuelas de Estudios Arabes de Madrid y Granada, 1950.

This book is still a standard work on Ibn al-Zarqālluh.

1344. Ibn al-Naqqās al-Zarqālluh. *al-Šakkāziyya. Edición, traducción y estudio por R. Puig.* Barcelona: Instituo "Millas Vallicrosa" de Historia de la Ciencia Árabe, 1988.

Edition of the Arabic text and Spanish translation of Ibn al-Zarqālluh's treatise on the Azafea, his new astrolabe plate for all geographical latitudes.

1345. Samsó, J. "Trepidation in al-Andalus in the 11th Century".

Published in item 1450. Analysis of Ibn al-Zarqālluh's theory.

Al-Mu'taman ibn Hūd

See also item 1287.

1346. Hogendijk, J. "The Geometrical Parts of the Istikmāl of Yūsuf al-Mu'taman ibn Hūd: An Analytical Table of Contents". *Archives Internationales d'Histoire des Sciences* 41 (1991), 207-281.

1347. Hogendijk, J. "Al-Mu'taman's Simplified Lemmas for Solving 'Alhazen's problem'".

Published in item 1438, Vol.1, 59-101. This fragment shows the originality of Al-Mu'taman, the king of Saragossa, as a geometer. See item 1328.

al-Khayyām, ʿUmar

1348. Woepcke, F. *L'algèbre d'Omar Alkhayyami*. Paris: B. Duprat, 1851.

Edition and French translation of ʿUmar Khayyam's *Algebra*, with translations of related texts by 10th century authors. Still useful.

1349. al-Khayyām. *L'oeuvre algèbrique d'al-Khayyām*. Edited by R. Rashed, and A. Djebbar. Aleppo: IHAS, 1981.

Includes the famous *Algebra* of al-Khayyām and a short algebraic treatise by al-Khayyām which was unknown to Woepcke. See also item 1434.

1350. Kasir, D. *The Algebra of Omar Khayyam*. New York: Columbia University, 1931.

English translation of the *Algebra* of al-Khayyām.

al-Ṭūsī, Sharaf al-Dīn

See also item 1395.

1351. al-Ṭūsī, Sharaf al-Dīn *Oeuvres Mathématiques: Algèbre et Géométrie au XIIe siècle*. Edited by R. Rashed Paris: Les Belles Lettres, 1986. 2 vols.

Includes Arabic text and French translation of the *Algebra* of Sharaf al-Dīn, in which he "solved" cubic equations by means of conic sections.

1352. Hogendijk, Jan P. "Sharaf al-Dīn al-Ṭūsī on the Number of Positive Roots of Cubic Equations". *Historia Mathematica* 16 (1989), 69-85.

English summary and analysis of the *Algebra* of Sharaf al-Dīn.

Ibn Munʿim

1353. Djebbar, A. *L'analyse combinatoire dans l'enseignement d'Ibn Munʿim (XIIe–XIIIe siècles)*. Université de Paris-Sud: Départment de Mathématique, 1982.

An important contribution to a previously unexplored aspect of Western Islamic mathematics.

al-Marrākushī

1354. Sedillot, J.-J., and L.-A. Sedillot. *Traité des instruments astronomiques des Arabes.* Paris: Imprimerie Royale, 1834.

Translation of the *Jāmi' al-mabādi' wa-l-ghāyāt fi*ʿ*ilm al-mīqāt* ("all beginnings and ends in the science of timekeeping") of al-Marrākushī. This text, which contains much information on arithmetic, trigonometry and sundials, was reprinted in 1984 by the Institute for the History of Arabic-Islamic Sciences in Frankfurt.

al-Ṭūsī, Nāṣīr al-Dīn

1355. al-Ṭūsī, Nāṣīr al-Dīn. *Traité du quadrilatère.* Edited by A. Carathéodory. Constantinople, 1891.

Text and French translation of Nāṣīr al-Dīn's book on Menelaos's theorem. Contains many historical remarks. On the history of this theorem see also item 1406.

1356. Ragep, J. *Nāṣīr al-Dīn al-Ṭūsī's Memoir on Astronomy.* New York: Springer, 1993.

Edition with English translation, commentaries and glossaries, of a fundamental introductory text on the structure of the universe.

Ibn Bāṣo, Abū ʿAlīal-Ḥusayn

1357. Ibn Bāṣo, Abū ʿAlīal-Ḥusayn. *Risālat al-Ṣafīḥ a al-Ŷāmiʿa li-Ŷamīʿal-ʿUrū̱ Tratado sobre la lámina general para todas las latitudes.* Edited by E. Calvo. Madrid: Instituto de Cooperación con el Mundo Árabe, 1993.

Edition of the Arabic text and Spanish translation of a treatise by Ibn Bāṣo, the time-keeper of the mosque of Granada in the late 13th century, on a new kind of astrolabe plate for all geographical latitudes.

Ibn al-Bannā'

1358. Ibn al-Bannā', Aḥmad b. Muḥammad. *Talkhiṣ aʿmāl al-ḥisāb.* Edited by M. Souissi. Tunis: Université de Tunis, 1969. .

Text of an arithmetical treatise, with French translation and commentary.

Al-Fārisī, Kamāl al-Dīn

1359. Ağargün, A. G., and C. R. Fletcher. "Al-Fārisī and the Fundamental Theorem of Arithmetic". *Historia Mathematica* 21 (1994), 162-173.

English translation and analysis of a treatise on divisibility of numbers.

Al-Khalīlī, Shams al-Dīn

1360. King, D. A. "Al-Khalīlī's Qibla-Table". *Journal of Near Eastern Studies* 34 (1975), 81–122.

Study of a set of tables for determining the direction of Mecca compiled by the astronomer Al-Khalīlī of Damascus.

1361. King, D. A. "Al-Khalīlī's Auxiliary Tables for Solving Problems of Spherical Astronomy". *Journal for the History of Astronomy* 4 (1973), 99–110.

1362. Van Brummelen, G. "The Numerical Structure of Al-Khalīlī's Auxiliary Tables". *Physis* 28 (1991), 667-697.

Discusses mathematical methodology for analyzing tables.

Ibn al-Shāṭir

1363. Kennedy, E. S., and I. Ghanem. *The Life and Work of Ibn al-Shāṭir, an Arab Astronomer of the Fourteenth Century.* Aleppo: University of Aleppo, 1976.

This volume contains biographical and bibliographical material on Ibn al-Shāṭir, as well as reprints of papers on the works of this astronomer, who is known for his non-Ptolemaic planetary and lunar theory. See also item 1415.

Al-Kāshī, Ghiyāth al-Dīn Jamshīd ibn Masʿūd

1364. Luckey, P. *Die Rechenkunst bei Ǧamšīd b. Masʿūd al-Kāšī* mit Rückblicken auf die ältere Geschichte des Rechnens. (Abhandlungen für dei Kunde des Morgenlandes, 31). Wiesbaden: F. Steiner, 1951, 143 pp.

Analysis of part of the †Key of Arithmetic† (*Miftāḥ al-Ḥisāb*) of al-Kāshī. This fundamental work has not yet been translated into a Western language.

1365. Aaboe, A. "Al-Kashi's Iteration Method for the Determination of Sin 1". *Scripta Mathematica* 20 (1954), 24-29.

Discusses a method of al-Kāshī on the basis of reports by commentators, see item 1373. Al-Kāshī's own treatise on the subject is lost.

1366. Luckey, P. *Der Lehrbrief über den Kreisumfang von Ǧamšīd b. Masʿūd al-Kāšī.* Translated by P. Luckey. Edited by A. Siggel. Berlin: Akademie Verlag, 1953.

Arabic text and German translation of the "Treatise on the Circumference" of al-Kāshī with commentary. Al-Kāshī determines π to 16 significant decimal digits.

1367. Kennedy, E. S. "Spherical Astronomy in Kāshī's Khāqānī Zīj". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften.* 2 (1985), 1-46.

1368. Dold-Samplonius, Y. "Practical Arabic Mathematics: Measuring the Muqarnas by al-Kāshī". *Centaurus* 35 (1992), 193-242.

Includes edition and English translation of the relevant chapter of the †Key of Arithmetic†, related to architecture.

1369. Dold-Samplonius, Yvonne. *Qubba for Al-Kāshī.* Providence, Rhode Island: American Mathematical Society, 1995.

This video shows a computer-generated construction of a mausoleum with cupola (qubba) for al-Kāshī, according to his own mathematical methods. Explanations are provided in a voice over the videotape and in an accompanying booklet.

1370. Kennedy, E. S. "A Letter of Jamshīd al-Kāshī to His Father: Scientific Research at a Fifteenth Century Court". *Orientalia* 29 (1960), 191-213.

Reprinted in item 1436. Translation of a letter which offers interesting details on life and work of mathematicians and astronomers in the court of the astronomer-king Ulugh Beg in 15th-century Samarkand. See also items 1371 and 1372.

1371. Sayili, A. *Ghiyāth al-Dīn al-Kāshī's Letter on Ulugh Bey and the Scientific Activity in Samarqand.* Ankara: Türk Tarih Kurumu Basımevi, 1960.

Persian text with Turkish and English translation of the same letter as in item 1370. See also item 1372.

1372. Bagheri, M. "A Newly Found Letter of Al-Kāshī on Scientific Life in Samarkand". *Historia Mathematica 24 (1997), 241-256.*

English translation of another letter of al-Kāshī to his father on scientific life in Samarkand, different from the letter in items 1370 and 1371.

Ulugh Beg

1373. Sédillot, L. P. E. A. *Prolégomènes des tables astronomiques d'Oloug-Beg.* Paris: Typographie de Firmin Didot Frères, 1853.

Persian text and French translation of the long introductory chapters to the astronomical tables produced at the court of king Ulugh Begh of Samarkand, who was a mathematician and astronomer himself. Includes passages on the determination of Sin 1^o by means of a cubic equation and iteration; see also item 1365.

Al-Qalaṣādī

1374. Woepcke, F. "Traduction du traité d'arithmétique d'Aboûl Haçan Ali Ben Mohammad Alkalçādī". *Atti dell'Accademia Pontificia dei Nuovi Lincei.* 12 (1858-9), 230-275.

French translation of a Western Arabic treatise on practical computation. Reprinted in item 1453.

Studies on Specific Topics

Transmission of Mathematics

See also items 1246, 1259, 1261 - 1269, 1305, 1401, 1403, 1404, 1440, 1441.

1375. Rosenthal, F. *The Classical Heritage in Islam.* Berkeley and Los Angeles: University of California Press, 1973.

On the impact of Greek science in general on Islamic civilization.

1376. Sabra, A. I. "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement". *History of Science* 25 (1987), 223-243.

Also on the problem of decline. Reprinted in item 1449.

1377. Berggren, J. L. "Islamic Acquisition of the Foreign Sciences: A Cultural Perspective". In: item 1440, pp. 263-284.

1378. Høyrup, J. "The Formation of 'Islamic Mathematics': Sources and Conditions". *Science in Context* 1 (1987), 281-329.

1379. Høyrup, J. "Al-Khwārizmī, Ibn Turk and the 'Liber Mensurationum': On the Origins of Islamic Algebra". *Erdem* 5 (1986), 445-484.

1380. Hogendijk, J. "Transmission, Transformation and Originality: the Relation of Arabic to Greek Geometry". In: item 1440, pp. 31–64.

1381. Pingree, David. "The Greek Influence on Early Islamic Mathematical Astronomy". *Journal of the American Oriental Society* 93 (1973), 32–44.

Mathematics in Specific Areas of the Islamic World

For mathematics in Islamic Spain see also items 1233, 1244, 1438, 1450; for the Maghreb see also items 1249, 1353, 1388.

1382. Djebbar, A. "Mathematics in Medieval Maghreb". *AMUCHMA Newsletter* 15 (1995), 3-42. Fundamental paper on medieval mathematics in the Western Islamic world. Available on internet at (http://www.math.buffalo.edu/mad/AMU/amu_chma_15.html)

1383. Djebbar, A. *Enseignement et recherche mathématiques dans le Maghreb des XIIIe–XIVe siècles*. Université de Paris-Sud: Départment de Mathématique, 1980.

1384. Kennedy, Edward S. "The Exact Sciences in Abbasid Iran", "The Exact Sciences in Iran under the Saljuqs and Mongols", and "The Exact Sciences in Timurid Iran", all chapters in *The Cambridge History of Iran*. Cambridge: Cambridge University Press, 1968. 8 vols.

1385. De Young, G. "Euclidean Geometry in the Mathematical Tradition of Islamic India". *Historia Mathematica* 22 (1995), 138-153.

On mathematics education in Islamic India, with emphasis on the transmission of Euclid's *Elements* and Arabic and Persian commentaries.

1386. King, D. A. "The Astronomy of the Mamluks". *Isis* 74 (1983), 531–555.

Surveys the achievements in mathematical astronomy in 13th- to 16th-century Egypt and Syria. Reprinted in item 1442.

1387. Samso, J., and J. Vernet. "The Development of Arabic Science in Andalusia".

Published in item 1252, Vol.1, pp. 243-275.

Arithmetic

See also items 1273, 1302, 1317, 1325, 1358, 1364, 1374.

1388. Djebbar, A. "Le traitement des fractions dans la tradition mathématique arabe du Maghreb". In *Histoire de fractions, fractions d'histoire*. Edited by P. Benoit, K. Chemla, and J. Ritter. Basel: Birkhäuser, 1992. 223-245.

1389. Luckey, P. "Die Ausziehung der n-ten worzel und der binomische Lehrsatz in der islamischen Mathematik". *Mathematische Annalen* 120 (1948), 217-274.

Survey article.

1390. Rebstock, U. *Rechnen im islamischen Orient: die literarischen Spuren der praktischen Rechenkunst*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1992.

Survey of practical arithmetic in Islamic civilization.

1391. Rashed, R. "L'extraction de la racine n$^{\text{ième}}$ et l'invention des fractions décimales (XI^{e}–XIII^{e} siècles)". *Archive for History of Exact Sciences* 18 (1978), 191–243.

Reprinted in items 1446 and 1447.

1392. Rashed, R. "L'induction mathématique: al-Karajī, as-Samawʿal". *Archive for History of Exact Sciences* 9 (1972), 1-21.

On binomial coefficients in a lost work of al-Karajī. Reprinted in items 1446 and 1447.

Irrational Magnitudes

See also items 1271, 1342, 1389, and see the section on Algebra.

1393. Matvievskaya, G. P. "The Theory of Quadratic Irrationals in Medieval Oriental Mathematics".

Published in item 1437, pp. 253-277. Survey article, on medieval developments of Euclid's theory of irrational magnitudes in Book X of the *Elements*.

Algebra

See also items 1272, 1285, 1290, 1291, 1320, 1348, 1349, 1350, 1351, 1352.

1394. Anbouba, A. "L'Algèbre Arabe aux IXe et Xe siècles. Aperçu général". *Journal for the History of Arabic Science* 2 (1978), 66-100.

1395. Rashed, R. "Résolution des equations numériques et algèbre: Sharaf al-Dīn al-Ṭūsī, Viète". *Archive for History of Exact Sciences* 12 (1974), 244-290.

Argues that Viète's methods for the numerical solution of equations were influenced by Islamic predecessors. Reprinted in items 1446 and 1447.

1396. Ruska, J. *Zur ältesten arabischen Algebra und Rechenkunst.* Heidelberg: Carl Winter's Universitätsbuchhandlung, 1917.

Terminological study of Islamic algebra. With index. Reprinted in item 1457, Vol. 5.

Number Theory, Indeterminate Equations, Magic Squares

See also items 1268, 1269, 1293, 1294, 1296, 1297, 1300, 1301, 1319, 1324, 1359.

1397. Naini, Alireza Djafari. *Geschichte der Zahlentheorie im Orient.* Braunschweig: Klose and Co., 1982.

The emphasis is on amicable and perfect numbers.

1398. Sesiano, J. "Herstellungsverfahren magischer Quadrate aus islamischer Zeit (I, II, II', III)". *Sudhoffs Archiv* 64 (1980), 187-96; 65 (1981), 251-65; 71 (1987), 78-89; 79 (1995), 193-226.

On a variety of Arabic treatises on methods of construction of magic squares.

1399. Sesiano, J. *Un traité médiéval sur les carrés magiques. De l'arrangement harmonieux des nombres.* Lausanne: Presses polytechniques et universitaires Romandes, 1996.

Arabic text and French translation of an anonymous treatise on the construction of magic squares.

Geometry

See items 1262, 1266, 1267, 1271, 1280, 1282, 1286 1287, 1292, 1295, 1298, 1299, 1303, 1304, 1305,1307 - 1313, 1321 - 1322, 1323, 1328, 1329, 1346, 1366, 1385, 1445, and the section on Trigonometry.

1400. Bode, P. "Die Alhazensche Spiegel-Aufgabe in ihrer historischen Entwicklung nebst einer analytischen Lösung des verallgemeinerten Problems". *Jahresberichte des Physikalischen Vereins zu Frankfurt am Main* (1891-1892), 63-107.

Discusses the "problem of Alhazen" and its mathematical context in the *Optics* of Ibn al-Haytham. See item 1328, and see item 1347 for some corrections to Bode's article.

1401. Hogendijk, J. "Greek and Arabic Constructions of the Regular Heptagon". *Archive for History of Exact Sciences* 30 (1984), 197-330.

With editions of treatises on the heptagon by pseudo-Archimedes and al-Sijzī.

1402. Jaouiche, Kh. *La théorie des parallèles en pays d'Islam.* Paris: Vrin, 1986.

Includes French translations of all available Arabic texts on the parallel postulate.

1403. Knorr, W. *Textual Studies in Ancient and Medieval Geometry.* Basel: Birkhäuser, 1992.

Includes editions of Arabic texts on the trisection of the angle and the construction of two mean proportionals.

1404. Kunitzsch, P. "Letters in Geometrical Diagrams: Greek - Arabic - Latin". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 7 (1991-2), 1-20.

With an appendix by E. S. Kennedy on pp. 21-22.

1405. Rosenfeld, B. A. *A History of non-Euclidean Geometry.* Translated from the Russian by Abe Shenitzer. New York: Springer, 1988.

This book contains a large chapter on Islamic work on the parallel postulate.

Trigonometry

See also items 1316, 1318, 1331 - 1337, 1341, 1355, 1365, 1367, 1436, 1445, and the sections on Timekeeping, Instruments, Mathematical Astronomy and Astrology.

1406. Bjørnbo, A. *Thābits Werk über den Transversalensatz (liber de figura sectore) mit Bemerkungen von H. Suter. Herausgegeben und ergänzt durch Untersuchungen über die Entwicklung der muslimischen sphärischen Trigonometrie von H. Bürger und K. Kohl.* Erlangen: Mencke, 1924.

The edition of (the medieval Latin translation of) Thābit's treatise on the transversal theorem is followed by a survey of the work of many Islamic authors on the theorem of Menelaus and related theorems in spherical trigonometry.

1407. Debarnot, M. T. "Introduction du triangle polaire par Abū Naṣr ibn 'Irāq". *Journal for the History of Arabic Science* 2 (1978), 126-136.

On the introduction of the polar triangle in spherical geometry.

1408. Debarnot, M. T. "Trigonometry".

Published in: item 1252, Vol. 2, pp. 495-538.

1409. King, D. "Universal Solutions to Problems of Spherical Astronomy from Mamluk Egypt and Syria". In *A Way Prepared: Essays on Islamic Culture in Honor of Richard Bayly Winder.* Edited by F. Kazemi, and R. D. McChesney. New York: New York University Press, 1988, 153-184. Reprinted in 1444.

Note: The word "Universal" in the title means: for all localities.

1410. Lorch, R. "Jābir ibn Aflaḥ and the Establishment of Trigonometry in the West".

Published (only) in: item 1445, no. VIII.

1411. Luckey, P. "Zur Entstehung der Kugeldreiecksrechnung". *Deutsche Mathematik* 5 (1940), 405-446.

A fundamental study of the emergence of the concept of angle in a spherical triangle in the 10th century.

Timekeeping

See also items 1283, 1284, 1334, 1436, 1438, 1443, 1445.

1412. King, D. "Mizwala". In *Encyclopaedia of Islam*. Vol. 7. 2nd ed., Leiden: Brill, 1991, 210-211.

Survey of sundials and sundial theory. Reprinted in item 1444.

1413. King, D. "Mīḳāt". In *Encyclopaedia of Islam*. Vol. 7 2nd ed. Leiden: Brill, 1991, 27-32.

Survey of timekeeping methods in the medieval and modern Islamic world. Reprinted in item 1444.

1414. Schoy, C. "Die Gnomonik der Araber". In *Die Geschichte der Zeitmessung und der Uhren*. Edited by E. von Basserman-Jordan. Berlin: De Gruyter, 1923.

A study of Islamic sundial theory, reprinted in item 1455.

1415. Janin, L. "Le Cadran Solaire de la Mosquée Umayyade à Damas". Centaurus 16 (1972), 285-298.

Drawings of an elaborate 19-th century horizontal sundial in the Omayyad Mosque in Damascus, which is a copy of the sundial of Ibn al-Shāṭir (14th century). Reprinted in item 1363.

Interpolation, Tables, Analysis of Tables

See also items 1248, 1276, 1289, 1436, 1437, 1442, and the section on Astronomy.

1416. Kennedy, Edward S. "A Survey of Islamic Astronomical Tables". *Transactions of the American Philosophical Society* New Series 46 (ii) (1956), 121–177.

Introduces the Arabic *zījes* (= astronomical handbooks with tables), listing the known ones, and gives details of twelve of them. A basic reference work, in which the author bases his conclusions upon the study of unedited Arabic and Persian manuscripts.

1417. King, D. "On the Astronomical Tables of the Islamic Middle Ages". *Studia Copernicana* 13 (1975), 37-56.

Survey article. Reprinted in item 1442.

1418. Hamadanizadeh, J. "A Survey of Medieval Islamic Interpolation Schemes".

Published in item 1437, pp. 143-152.

1419. Rashed, R. "Al-Samawʿal, Al-Bīrūnī et Brahmagupta: Les méthodes d'interpolation". *Arabic Sciences and Philosophy*. 1 (1991), 101-160.

Includes Arabic text and French translation of a passage from a work by al-Samawʿal, which contains information on a lost work by al-Bīrūnī in which the latter described non-linear interpolation methods by Brahmagupta. Reprinted in item 1448.

1420. Mielgo, H. "A Method of Analysis for Mean Motion Astronomical Tables".

Published in item 1438, pp. 159-179.

1421. Van Dalen, B. "A Statistical Method for Recovering Unknown Parameters from Medieval Astronomical Tables". *Centaurus* 32 (1989), 85-145.

With applications to the solar equation tables in the *Shāmil Zīj* (13th century) and an oblique ascension table in the *SanjufīnīZīj* (14th century).

Cultural Context; Islamic Aspects

Most items in this bibliography on Islamic mathematics involve the cultural or Islamic context to a greater or lesser extent. See especially items 1236, 1253, 1254, 1306, 1326, 1340, 1360, 1370, 1371, 1372, 1376, 1377, 1385, 1390, 1428, 1444, 1449, and see the section on Mathematics, Art and Architecture.

1422. King, D. "Science in the Service of Religion: the Case of Islam". Vol. 159. (Impact of Science on Society.) Paris: Unesco, 1990.

Very accessible survey. Reprinted in item 1444.

1423. King, D. "Ḳibla". In *Encyclopaedia of Islam.* Vol. 5. 2nd ed. Leiden: Brill, 1979, 83-88.

Introduction to medieval methods for finding the qibla (or direction of Mecca) for prayer. Reprinted in item 1444.

1424. King, D. "The Earliest Islamic Mathematical Methods and Tables for Finding the Direction of Mecca". *Zeitschrift für Geschichte der arabisch-islamischenWissenschaften* 3 (1986), 82-149.

Reprinted in item 1444.

1425. Sabra, A. I. "Situating Arabic Science: Locality versus Essence". *Isis* 87 (1996), 645-670.

Mathematical Astronomy and Astrology

See also items 1236, 1237 (Vols. 6, 7), 1281, 1288, 1310, 1315, 1330, 1339, 1343, 1345, 1356, 1363, 1428, 1430, 1432, 1433, 1436, 1437 - 1438, 1439, 1442 - 1445, 1450, 1452, 1457, and the section on Instruments.

1426. Saliba, G. "Arabic Planetary Theory after the Eleventh Century A.D."

Published in item 1252, Vol.1, pp. 58-127.

1427. Kennedy, Edward S. "The Astrological Houses as Defined by Medieval Islamic Astronomers".

Published in item 1438 pp. 535-578. Survey article.

Instruments

See also items 1303, 1344, 1354, 1357, and the sections on Timekeeping and Astronomy.

1428. Sayili, A. M. *The Observatory in Islam and its Place in the General History of the Observatory.* Vol. 38. (Turkish Historical Society Publications, series 7.) Ankara: Turkish Historical Society, 1960.

The standard source on the subject.

1429. Schmidt, F. *Geschichte der geodätischen Instrumente und Verfahren im Altertum und Mittelalter.* Erlangen, 1929.

Description of the astronomical and geodetical instruments of antiquity and the middle ages, in 400 pages with index. Reprinted in item 1458, Vol. 5.

1430. King, D. "The Medieval Yemeni Astrolabe in the Metropolitan Museum of Art in New York City". *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 2 (1985), 99-122.

A nice example of an astrolabe, with photographs and some explanation of the underlying mathematics. Reprinted in item 1443.

1431. King, D. "An Analog Computer for Solving Problems of Spherical Astronomy: the shakkāziya quadrant of Jamāl al-Dīn al-Māridīnī". *Archives Internationales d'Histoire des Sciences* 24 (1974), 219-242.

Includes a mathematical analysis of the instrument. Reprinted in item 1443.

1432. Michel, Henri. *Traité de l'astrolabe.* Paris: Gauthier-Villars, 1947, viii + 202 pp., 24 pls.

This book explains the use and mathematical theory of astrolabes. For a brief elementary explanation of the astrolabe in English, see J. D. North, "The Astrolabe", *Scientific American* 230 (1) (January 1974), 96–106.

1433. Schmalzl, P. *Zur Geschichte des Quadranten bei den Arabern.* München: Druck der Salesianischen Offizin, 1929.

On the history of the quadrant in Islamic mathematics and astronomy. Reprinted in item 1458, Vol. 6.

Mathematics, Art and Architecture

See also items 1258, 1309, 1368, 1370.

1434. Özdural, A. "Omar Khayyam, Mathematicians and Conversazioni with Artisans". *Journal of the Society of Architectural Historians* 54 (1995), 54-71.

Establishes a connection between a certain triangle constructed by al-Khayyām in a work on algebra (see item 1349) and mosaic drawings.

1435. Özdural, A. "On interlocking similar or corresponding figures and ornamental patterns of cubic equations". *Muqarnas* 13 (1996), 191-211.

Partial analysis of a 16th-century Persian manuscript with mosaic drawings, some of which cannot be constructed by means of ruler and compass.

Optics

See items 1267, 1311, 1312, 1327, 1360, 1361, 1362, 1439, 1448, 1449.

Geography

See items 1248, 1332, 1337.

Reprinted Works and Collections of Articles

1436. Kennedy, E. S., et al. *Studies in the Islamic Exact Sciences.* Edited by D. A. King, and M.-H. Kennedy. Beirut: American University of Beirut Press, 1983.

Numerous articles by E. S. Kennedy, colleagues, and students are reprinted in this volume.

1437. King, D. A., and G. Saliba, eds. *From Deferent to Equant: A Volume of Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy.* New York: The New York Academy of Science, 1987.

1438. Casulleras, J. and J Samsó., eds. *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet.* Barcelona: Universitat de Barcelona, 1996. 2 vols.

1439. Wiedemann, E. *Aufsätze zur arabischen Wissenschaftsgeschichte.* Hildesheim: Olms, 1970. 2 vols.

This is a reprinting, in two volumes, of Wiedemann's articles on Islamic science which originally appeared in the *Sitzungsberichte der phys.-mediz. Sozietät* in Erlangen as "Beiträge zur Geschichte der Naturwissenschaften" (1902–1928). The other papers of Wiedemann are reprinted in item 1456.

1440. Ragep, F. J., and S. P. Ragep, eds. *Tradition, Transmission, Transformation. Proceedings of two conferences on pre-modern science held at the University of Oklahoma.* Leiden: Brill, 1996.

1441. Folkerts, M. *Mathematische Probleme im Mittelalter: Der lateinische und arabische Sprachbereich*. Wiesbaden: Harrassowitz, 1996.

Ten articles in this conference proceedings concern Islamic mathematics.

1442. King, D. *Islamic Mathematical Astronomy*. Aldershot: Variorum, 1985.

Reprints of 18 articles, with index. Second edition 1993.

1443. King, D. *Islamic Astronomical Instruments*. Aldershot: Variorum, 1986.

Reprints of 22 articles, with index.

1444. King, D. *Astronomy in the Service of Islam*. Aldershot: Variorum, 1985.

Reprints of 14 articles, with index.

1445. Lorch, R. *Arabic Mathematical Sciences: Instruments, Texts, Transmission*. Aldershot: Variorum, 1995.

Reprints of 18 articles, with index.

1446. Rashed, R. *Entre arithmétique et algèbre. Recherches sur l'histoire des mathématiques Arabes*. Paris: Les Belles Lettres, 1984.

Reprints of articles in the period 1970-1984. See item 1447.

1447. Rashed, R. *The Development of Arabic Mathematics: Between Arithmetic and Algebra*. Dordrecht: Kluwer, 1994.

English translation of item 1446.

1448. Rashed, R. *Optique et mathématiques. Recherches sur l'histoire de la pensée scientifique en Arabe*. Aldershot: Variorum, 1992.

1449. Sabra, A. I. *Optics, Astronomy and Logic*. Aldershot: Variorum, 1994.

Reprints of 17 articles, with index.

1450. Samso, J. *Islamic Astronomy and Medieval Spain*. Aldershot: Variorum, 1994.

Reprints of 20 articles, with index.

1451. von Gotstedter, A. *Ad Radices: Festband zum fünfzigjährigen Bestehen des Instituts für Geschichte der Naturwissenschaften der Johann-Wolfgang Goethe-Universität Frankfurt am Main*. Stuttgart: Franz Steiner Verlag, 1994.

Some papers are on Islamic mathematics and mathematical astronomy.

1452. Saliba, G. *A History of Arabic Astronomy: Planetary Theories during the Golden Age of Islam*. New York: New York University Press, 1994.

Reprints of articles on non-Ptolemaic planetary theories in the later centuries of Islamic astronomy.

Institute of the History of Arabic-Islamic Sciences Series

Since 1985 the Institute of the History of Arabic-Islamic Sciences in Frankfurt (Germany) has reprinted almost all of the literature on Islamic mathematics published before ca. 1960. These publications are enormously useful for finding obscure articles and books in the field. A list of the most important reprints on Islamic mathematics in Western languages follows. In addition, the Institute is also putting out reprints of Arabic editions and facsimiles of Arabic manuscripts of mathematical and astronomical texts. These will not be mentioned below.

1453. Woepcke, Franz. *Études sur des mathématiques arabo-islamiques. Nachdruck von Schriften aus den Jahren 1842-1874*. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1986. 2 vols.

The collected works of Franz Woepcke.

1454. Suter, H. *Beiträge zur Geschichte der Mathematik and Astronomie im Islam. Nachdruck seiner Schriften aus den Jahren 1892-1922*. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1986. 2 vols.

The collected works of Heinrich Suter.

1455. Schoy, C. *Beiträge zur arabisch-islamischen Mathematik und Astronomie. Nachdruck von Schriften aus den Jahren 1911-1926*. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1988. 2 vols.

The collected works of Carl Schoy.

1456. Wiedemann, E. *Gesammelte Schriften zur arabisch-islamischen Wissenschaftsgeschichte*. Edited by D. Girke. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1984. 3 vols.

With index. Contains reprints of all papers not included in item 1439.

1457. Sezgin, F. *Islamic Mathematics and Astronomy*. Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1997- .

This is a collection of reprints, which will, once completed, amount to more than 100 volumes. Practically all the literature on Islamic mathematics published before 1960 will be reprinted in these volumes. The volumes are compiled thematically, for example Vols. 1-4 are about Al-Khwārizmī, Vols. 14-20 on Euclid in the Arabic tradition, Vols. 21-22 on Tābit ibn Qurra, Vol. 23 on Abū Kāmil, Vols. 24-25 on Ibn Yūnis, Vol. 32-36 on al-Bīrūnī, etc.

1458. Sezgin, F. *Arabische Instrumente in orientalistische Studien.* Frankfurt: Institut für Geschichte der arabisch-islamischen Wissenschaften, 1990.

Reprints of articles on Islamic astronomical instruments in Western languages and in Arabic, published between 1801 and 1931, in six volumes.

INDIAN MATHEMATICS

Mathematics in India can be traced back to the *Vedas* (ca. 1200–800 B.C.), relatively new strata of which show a keen interest in mathematical series such as those of natural numbers, of odd numbers, of even numbers, of multiples of four, five, ten, etc., an interest which continued to engage the mathematical minds of the Indian people over two millennia and finally resulted in the discovery of power series expansions of trigonometric functions in the 14th-15th centuries A.D.

Geometric knowledge of the Vedic and subsequent periods are preserved in Śulba (also spelled Śulva) works (6th century B.C. and later), which are basically compilations of practical rules for the construction of altars used in Vedic rituals. Numerical preciseness was required in the measurement of the size of altar and ritual sites and in the number and size of bricks used for the former. The Śulba works, however, also contain mathematical theorems of a general character, among which are the oldest extant verbal expressions of the so-called Pythagorean Theorem and various rules, exact or approximate, for transforming geometric figures without changing their areas.

The Brāhmī script, which was employed in most of the edicts of the king Aśoka (ca.268–232 B.C.), had a system of numeral notation, where individual symbols were used for tens, hundred, and thousand as well as for one to nine, and composite symbols based on the principle of either addition or multiplication for multiples of hundred and thousand. Various scripts were to develop later from this script in India and in neighboring countries.

In the Buddhist and the Jaina, as well as epic and political literatures, mentions are made of a profession called "calculator" (gaṇaka or saṃkhyāyaka), whose main work was accountancy.

In several centuries before and after the Christian era, the Jaina people played a very important role in the making of Indian mathematics (gaṇita). They developed basic theories of combinatorics, of infinite quantities, of laws of indices, and of geometric formulas for a circle and its segment. All these topics were related to their religious and philosophical doctrines as well as to their cosmography.

A kind of abacus based on the decimal place-value system, where sticks (vartikās) or beads (gulikās) were used as counters, was in use in India in the early centuries of the Christian era, and a decimal place-value notation for writing numbers, where numbers from one to nine were expressed by the old Brāhmī numerals for the same and a vacant (śūnya) place by a dot (bindu), was invented at the latest by the 6th century A.D.

Āryabhaṭa I, one of the founders of Indian mathematical astronomy based on the epicyclic and eccentric models of planetary motion and on plane trigonometry of Greek origins, included a chapter on gaṇita in his astronomical work, *Āryabhaṭīya* (A.D. 499 or a little later), in which he treated, among other things, proportion ("rule of three"), plane trigonometry (an exact relationship between consecutive sine-differences of a sine table, etc.), and linear indeterminate equations (a complete solution called kuṭṭaka or pulveriser). These three topics, together with the projection of spherical entities onto plane surfaces, constituted the major part of the mathematical bases for Indian astronomy.

Varāhamihira (6th century A.D.), an authority on astrology and divination, classified gaṇita as one of the three branches of jyotiḥśāstra (astral science); the other two are horā or horoscopic astrology and saṃhitā or divination (lit. collection). This gaṇita included mathematical astronomy besides mathematics. Major treatises on mathematical astronomy written after him, called siddhānta, often included a few chapters on mathematics. His own edition of the five then-existing siddhāntas, the *Pañcasiddhāntikā*, does not have such a chapter but contains the oldest extant evidence of the treatment of zero as a number. His work on divination, the *Bṛhatsaṃhitā*, contains an irregular magic square of order four and a method for constructing the so-called Pascal's triangle.

Brahmagupta divided mathematics into two fields and treated them respectively in Chapters 12 and 18 of his *Brāhmasphuṭasiddhānta* (A.D. 628); the former chapter, simply called gaṇita, treats the arithmetic operations of integers and fractions and eight kinds of "practical (or applied) mathematics" such as "mixture", "plane figures". "series", etc., while the latter, named after the first topic of the chapter, i.e., kuṭṭaka, treats algebraic equations in addition to the arithmetic operations involving negative numbers, zero, irrational numbers, and unknown quantities, for the last of which he presumably employed symbolic expressions. Thus, by the first half of the 7th century, Indian mathematicians had obtained a large domain of numbers in which they could skillfully solve determinate and indeterminate equations of the first and the second degrees including the so-called Pell's equation (called varga-prakṛti or square-nature). The same work also contains other mathematical topics such as combinatorics and trigonometry. Bhāskara I wrote an elaborate prose commentary (A.D. 629) on the *Āryabhaṭīya*. It is historically important since it preserves more details of the 7th-century Indian mathematics than Brahmagupta's work, which is written in verse. Perhaps contemporaneous to Brahmagupta and Bhāskara I is an anonymous work on arithmetic preserved in a birch bark manuscript called the *Bakhshālī Manuscript*, which is palaeographically assignable to some time between the 8th and the 12th centuries.

By the first half of the 7th century, "a calculator" came to signify "one who knows mathematical astronomy or horoscopic astrology" besides "an accountant". Both Brahmagupta and Bhāskara I used the word gaṇaka in that sense. By the 8th century, Brahmagupta's two divisions of mathematics, gaṇita and kuṭṭaka, became the two major fields of gaṇita called respectively pāṭīgaṇita or "mathematics of algorithms" (roughly corresponding to arithmetic and mensuration) and bījagaṇita or "mathematics of seeds" (corresponding to algebra; "seeds" are equations). Bījagaṇita has been the source of pāṭīgaṇita so far as it was used to generate algorithms.

Śrīdhara (8th century) was perhaps the first to write books on mathematics proper in both fields, although his work on bījagaṇita is known only from references by later writers. A Jaina mathematician, Mahāvīra (ca. A.D. 850), wrote a voluminous book on algorithms comprising more than 1130 verses for rules and examples. A prolific writer on astronomy and astrology, Śrīpati included two chapters, vyaktagaṇita (mathematics of known quantities) and avyaktagaṇita (mathematics of unknown quantities), which correspond respectively to pāṭīgaṇita and bījagaṇita, in his *Siddhāntaśekhara* (ca. A.D. 1039). The latter chapter shows an intermediate stage of the developments of bījagaṇita between Brahmagupta and Bhāskara II.

The most famous mathematician in medieval India was Bhāskara II, who wrote the *Līlāvatī* on pāṭīgaṇita and the *Bījagaṇia* on bījagaṇita (both by A.D. 1150). The former work, written in plain and elegant Sanskrit verses and well organized, was welcomed all over India as a textbook of arithmetic and mensuration. Most of the topics treated in it were traditional ones but he added an entirely new chapter (called "net of digits") which treats combinatorics. The latter work, though less popular, shows a culmination of Indian algebra. In his astronomical works, he proved formulas for the volume and the surface of a sphere by decomposing them into small pieces, and used an equivalent of the differential of sine in his computation of the instantaneous motion of a planet.

Nārāyaṇa, too, wrote one book each in both fields. In his *Gaṇitakaumudī* (A.D. 1356), he not only treated the ordinary topics of pāṭīgaṇita but also greatly developed the topics of factorization, partitioning, combinatorics, and magic squares in the last four chapters. His contribution to algebra is yet to be investigated as his work on bījagaṇita is only partially available now.

Trigonometry was traditionally associated with astronomy. Āryabhaṭa I devoted two verses to it in the above mentioned mathematical chapter, but after him this topic was treated almost always in a chapter (or a book) not on mathematics proper but on astronomy. There were continuous developments in this field until the 18th century: especially noteworthy is the discoveries of series expansions of π and of several trigonometric functions such as sine, cosine, and arctangent by the Kerala school of mathematics and astronomy headed by Mādhava (ca. A.D. 1380/1420).

The transmission of mathematical knowledge between India and other cultural areas may naturally be expected to have taken place from time to time in one direction or another, but the various attempts so far made to prove it do not seem to be very successful for the periods before the contact of India and Islam except for the mathematical apparatus for astronomy such as the epicyclic and eccentric models for planetary motion, plane trigonometry and the sexagesimal notation of numbers, and for the decimal place-value system with Indian numerals.

The present bibliography covers studies of these subjects and editions of texts together with their translations. General reference works cited here will greatly facilitate further reference.

Periodicals: *Gaṇita Bhāratī (Bulletin for the Indian Society for History of Mathematics)* is mostly devoted to the history of Indian mathematics. Articles on Indian mathematics frequently appear also in the *Indian Journal of History of Science*, less frequently in journals designed for the history of exact sciences such as *Historia Mathematica*, *Centaurus*, *Archive for History of Exact Sciences*, etc., and sometimes in journals for history of science as well as in those for Oriental and Indological studies.

General Reference Works

1459. Pingree, David. *Census of the Exact Sciences in Sanskrit, Series A*, vols. 1–5. (Memoirs of the American Philosophical Society, 81, 86, 111, 146, 213.) Philadelphia: American Philosophical Society, 1970–1994.

An exhaustive work in progress to provide all available bibliographical information concerning works in jyotiḥśāstra and related fields and biographical information concerning their authors. The first five volumes contain articles on the authors whose names begin with the vowel *a* to the labial *v* in the order of the Sanskrit alphabet. See also articles by Pingree in the *Dictionary of Scientific Biography* (ed. C. C. Gillispie), including item 1506, which give ample biographical and bibliographical data for major Indian mathematicians and astronomers.

1460. Pingree, David. *Jyotiḥśāstra: Astral and Mathematical Literature*. (A History of Indian Literature, 6, fasc. 4.) Edited by J. Gonda. Wiesbaden: Otto Harrassowitz, 1981.

Chronological description of the literature of the jyotiḥśāstra ("astral science" including mathematics, astronomy, horoscopic astrology, and various kinds of divination) according to the fields in 9 chapters: Śulbasūtras, Astronomy, Mathematics, Divination, Genethlialogy, Catarchic Astrology, Interrogations, Encyclopaedias and Dictionaries, and Transmission of Jyotiḥśāstra. A mine of bibliographic information.

1461. Raja, K. Kunjunni. "Astronomy and Mathematics in Kerala: An Account of the Literature". *Brahmavidyā* (Adyar Library Bulletin, Madras) 27 (1963), 118–167.

Provides biographical and bibliographical information about 17 major mathematicians and astronomers in Kerala beginning with the legendary astronomer Vararuci, traditionally ascribed to the 4th century A.D., and ending with Śaṅkaravarman of the 19th century.

1462. Sarma, K. Venkateswara. *A History of the Kerala School of Hindu Astronomy: In Perspective*. Hoshiarpur: Visheveshvaranand Institute, 1972.

The first 3 chapters describe characteristic features of the Kerala astronomy and mathematical bases for it, and the next 3 chapters provide biographical information about nearly 80 Kerala astronomers and mathematicians from the 4th to the 20th centuries and bibliographical (manuscript) information about Kerala and Kerala-based literature on jyotiṣa (astral science). The last 2 chapters on bibliographies have been separately published as *A Bibliography of Kerala and Kerala-based Astronomy and Astrology*, Hoshiarpur: Visheveshvaranand Institute, 1972.

1463. Selin, Helaine. *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*. Dordrecht: Kluwer Academic Publishers, 1997.

Includes a number of articles on authors and works as well as on various topics in Indian mathematics with useful bibliographies for each entry. Some of the articles are cited in other items in this section.

1464. Sen, Samarendra Nath, Amulya Kumar Bag, and Sreeramula Rajeswara Sarma. *A Bibliography of Sanskrit Works on Astronomy and Mathematics, Part 1: Manuscripts, Texts, Translations, and Studies*. New Delhi: National Institute of Sciences of India, 1966.

A bibiliography of a moderate size, according to Sanskrit authors and titles, with annotations for the major works.

1465. Subbarayappa, B. V., and K. Venkateswara Sarma. *Indian Astronomy: A Source Book*. Bombay: Nehru Centre, 1985.

Provides, in total, nearly 3000 Sanskrit verses on various topics extracted from different astronomical works with their English translations and notes. Consists of 22 chapters divided in 5 parts: General Ideas and Concepts (astronomy, astronomer, cosmogony, views and concepts, erroneous notions, numeration, measures of time, etc.), Astronomical Instruments (armillary sphere, observatories, instruments), Computations (calendar, stars and asterisms, planets, precession of the equinoxes, gnomonic shadow), Occultation (eclipses, phases of the moon, heliacal rising and setting of planets and stars, conjunctions of planets, conjunctions of stars and planets), and Innovative Trends (novel innovations, rationale of astronomy). Table of Indian eras, select bibliography of Indian astronomy (in chronological order), general bibliography, glossary, lists of word-numerals and of sources and translators, and general index are appended.

Sources and Translations

1466. *Aṇuogaddāra* (3rd–5th century A.D.). Edited by Puṇyavijaya, Dalsukh Mālvaṇiā, and Amritlāl Mohanlāl Bhojak. *Nanidsuttam and Aṇuogaddārāiṃ.* (Jaina Āgama Series 1.) Bombay: Śrī Mahāvīra Jaina Vidyālaya, 1968, 59–441.

An encyclopedic work of Jainism written in Ardhamāgadhī. Contains mathematical topics such as combinatorics, the law of indices on base 2, a system of countable, uncountable and infinite numbers, etc. For an English translation, see Taiken Hanaki, *Aṇuogaddārāiṃ: English Translation* (Prakrit Jain Institute Research Publications Series 5), Vaishali: Research Institue of Prakrit, Jainology & Ahimsa, 1970.

1467. Āryabhaṭa I (b. A.D. 476). *Āryabhaṭīya.* (A.D. 499 or a little later). Edited by Kripa Shankar Shukla and K. Venkateswara Sarma. (Āryabhaṭīya Critical Edition Series 1.) New Delhi: Indian National Science Academy, 1976. In Sanskrit.

An astronomical work. With English translation and comments. Consists of 4 chapters, which treat respectively astronomical constants, mathematics, computation of time (calendar), and spherical astronomy. For a German translation of the second chapter together with a study, see Kurt Elfering, *Die Mathematik des Āryabhaṭa I* (Munich: Wilhelm Fink Verlag, 1975). For other translations see D. Pingree's work, *Census* (item 1459), Series A, Vol. 1, 53a, and Series A, Vol. 5, 17a.

1468. Āryabhaṭa II (ca. A.D. 950 or 1500). *Mahāsiddhānta.* Edited by Sudhākara Dvivedin. (Benares Sanskrit Series Nos. 148, 149, and 150.) Benares: Braj Bhushan Das & Co., 1910. Reprinted in one volume. (Vrajajīvana Prācya Granthamālā 81.) Delhi: Chaukhamba Sanskrit Pratishthan, 1995. In Sanskrit.

An astronomical work with editor's commentary. The first 13 chapters have been edited, with English translation and a glossary-index of Sanskrit astronomical terms, by Sreeramula Rajeswara Sarma: *The Pūrvagaṇita of Āryabhaṭa's (II) Mahāsiddhānta*, Parts 1 and 2, (dissertation, Philipps-Universität zu Marburg), Marburg: Erich Mauersberger, 1966. No modern translation of the two chapters devoted to mathematics (Chap. 15 for pāṭī and Chap. 18 for kuṭṭaka) exists, though English translation of his rule for the extraction of the cube root is available in: V. N. Jha, "Āryabhaṭa II's Method for Finding

Cube-Root of a Number", *Gaṇita Bhāratī* 19 (1997), 60–68. For the date of Āryabhaṭa II, see under R. Billard, item 1497.

1469. *Bakhshālī Manuscript.* (Presumably 7th century A. D.). Edited by Hayashi, Takao, *The Bakhshālī Manuscript: An Ancient Indian Mathematical Treatise.* (Groningen Oriental Series 11.) Groningen: Egbert Forsten, 1995.

A diplomatic edition of the anonymous manuscript on arithmetic written in Sanskrit, with an introduction, English translation of the whole text, mathematical commentaries on all the rules and examples in the text, and appendices. The English translation is based on a detailed study of the linguistic peculiarities of the text. The editor assigns the work to the 7th century based mainly on its similarity, in style of writing and technical terms, with Bhāskara I's commentary (A.D. 629) on the *Āryabhaṭīya.*

1470. Bhāskara I. *Āryabhaṭīyabhāṣya.* (A.D. 629). Edited by Kripa Shankar Shukla. *Āryabhaṭīya of Āryabhaṭa with the Commentary of Bhāskara I and Someśvara.* (Āryabhaṭīya Critical Edition Series 2.) New Delhi: Indian National Science Academy, 1976. In Sanskrit.

Valuable commentary on the *Āryabhaṭīya* of Āryabhaṭa I. Edited with informative introduction and English translation of Bhāskara I's examples. Bhāskara I's commentary is available up to Verse 6 of the last (4th) chapter of the *Āryabhaṭīya*; for the rest of the work, Someśvara's commentary (11th or 12th century A.D.), which is claimed to be a summary of Bhāskara I's, is provided. For the mathematical contents, see Kripa Shankar Shukla "Hindu Mathematics in the Seventh Century as Found in Bhāskara I's Commentary on the *Āryabhaṭīya*, *Gaṇita* 22 (1), 1971, 115–130; 22 (2), 1971, 61–78; 23 (1), 1972, 57–79; and 23 (2), 1972, 41–50. "

1471. Bhāskara I. *Mahābhāskarīya.* Edited by T. S. Kuppanna Sastri. *Mahābhāskarīya of Bhāskarācārya.* (Madras Government Oriental Series 130.) Madras: Government of Madras, 1957. Also edited by Kripa Shankar Shukla. *Bhāskara I and His Works, Part II: Mahābhāskarīya.* (Hindu Astronomical and Mathematical Texts Series 3.) Lucknow: Lucknow University, 1960. In Sanskrit.

An astronomical work. Contains a section on the kuṭṭaka theory (integer solutions to indeterminate equations of the first degree). Sastri's edition is provided with the editor's introduction, the commentary of Govindasvāmin (fl. 800/850) and the super-commentary (ca.1432) of Parameśvara, while Shukla's with English translation accompanied by helpful notes.

1472. Bhāskara II (b. A.D. 1114, d. after 1183). *Bījagaṇita.* Edited by Dattātreya Āpaṭe, et al. (Ānandāśrama Sanskrit Series No. 99.)

Poona: Ānandāśrama Press, 1930. Also edited by Achyūtānanda Jhā. *The Bījagaṇita (Elements of Algebra) of Śrī Bhāskarāchārya.* (Kāśī Sanskrit Series 148.) Benares: The Chowkhamba Sanskrit Series Office, 1949. In Sanskrit.

A book on algebra. Āpaṭe's edition is accompanied by the commentary of Kṛṣṇa, while Jhā's by the commentaries of Jīvanātha Jhā and of the editor. For an English translation, see the work by Colebrooke, item 1554.

1473. Bhāskara II. *Līlāvatī.* Edited by Dattātreya Āpaṭe, et al. (Ānandāśrama Sanskrit Series No. 107.) Poona: Ānandāśrama Press, 1937. Also edited by K. Venkateswara Sarma. (Vishveshvaranand Indological Series 66.) Hoshiarpur: Vishveshvaranand Vedic Research Institute, 1975. In Sanskrit.

A book on arithmetic and mensuration (pāṭī). Āpaṭe's edition is accompanied by the commentaries of Gaṇeśa and of Mahīdhara, while Sarma's by that of Śaṅkara and Nārāyaṇa (see item 1485). The former edition represents the northen recension of the text, while the latter represents the south. The latter differs from the former in a number of verbal expressions, in the arrangement of some topics, and in some numerical data. For the last point see R. C. Gupta, "The Līlāvatī Rule for Computing Sides of Regular Polygons", *The Mathematics Education* 9 (2) (1975), B 25–29. For an English translation, see the work by Colebrooke, item 1554. For studies of its influence upon non-mathematical literature see T. Hayashi's articles, "Ritual Application of Mensuration Rules in India: An Edition of Gaṇeśa's *Kuṇḍasiddhyudāhṛti* with Mathematical Commentary", *Bulletin of the National Museum of Ethnology* 12 (1987), 199–224; and "The Mathematical Section of the *Nāradapurāṇa*, *Indo-Iranian Journal* 36 (1993), 1–28. "

1474. Brahmagupta (b. A.D. 598, d. after 665). *Brāhmasphuṭasiddhānta* (A.D. 628). Edited by Sudhākara Dvivedin. "The Brāhmasphutasiddhānta and Dhyānagrahopadeśādhyāya". *The Paṇḍits* New Series 23 (1901), 309–324, 389–404, 453–468, 517–532, 581–596, and 645–660; New Series24 (1902), 1–16, 65–80, 137–142, 209–240, 273–312, 321–360, 385–416, 465–496, 529–576, 593–624, 657–688, and 721–755.Reprinted in one volume, Benares: Medical Hall Press, 1902.Also edited by Ram Swarup Sharma, et al., *Brāhmasphuṭasiddhānta with Vāsanā, Vijñāna and Hindi Commentaries.* New Delhi: The Indian Institute of Astronomical and Sanskrit Research, 1966. 4 vols. In Sanskrit with Sanskrit and Hindi commentary.

An astronomical work containing several chapters on mathematics: Chapters 12 (arithmetic and mensuration), 18 (algebra), 19 (computation with a gnomon and shadows), and 20 (combinatorics on prosody; this chapter has not been deciphered yet). Chapter 21 (spherics) contains a section on "sine production" (how to derive 24 sines in a quadrant). Dvivedin's edition, which is based on a single manuscript, is accompanied by his own Sanskrit commentary, and Sharma's, based on four manuscripts, by his own Sanskrit and Hindi commentary and excerpts from those of Pṛthūdakasvāmin (fl. A.D. 864) and of S. Dvivedin. Vol. 1 of Sharma's work contains an introduction by Satya Prakash entitled "A Critical Study of Brahmagupta and His Works", which has been reprinted separately as *Brahmagupta and His Works* by the same publisher (New Delhi: The Indian Institute of Astronomical and Sanskrit Research, 1968). For an English translation of Chapters 12 and 18 see Colebrooke as cited in item 1554. For studies of Brahmagupta's mathematics see Pottage's article, item 1546, and Chapters 8 (Brahmagupta and Arithmetic) and 9 (Brahmagupta as an Algebraist) of Satya Prakash's introduction to Sharma's edition.

1475. Govindasvāmin (fl. ca. 800/850). *Mahābhāskarīyabhāṣya.* In Sanskrit.

Commentary on the *Mahābhāskarīya.* See under Bhāskara I (item 1471).

1476. Jagannātha Samrāṭ (fl. ca. 1720/1740). *Rekhāgaṇita.* Vols. 1 and 2. Edited by Harilāl Dhruva and Kamalāśaṅkara Trivedin.(Bombay Sanskrit Series 61–62.) Bombay: Government Central Book Depot, 1901/1902.

A Sanskrit translation, in 15 chapters, of Naṣīr al-Dīn al-Ṭūsī's Arabic recension of Euclid's *Elements.* No modern translation available. For a study of the Sanskrit terminology used in the translation see L. J. Rocher's article, item 1584. For the academic environment in which Jagannātha worked and for his attitude toward science see D. Pingree's article, "Indian and Islamic Astronomy at Jayasiṃha's Court", *Annals of the New York Academy of Science* 500 (1987), 313–328.

1477. Jadivasaha (Yativṛṣabha in Sanskrit, ca. 600). *Tiloyapaṇṇattī* (†Trilokaprajñapti†.) Edited by A. N. Upadhye, and H. L. Jain. *Tiloyapaṇṇattīof Yativṛṣabha.* Vols. 1 and 2. (Jīvarāja Jaina Granthamālā 1.) Sholapur: Jaina Saṃskṛti Saṃrakshaka Saṃgha, 1943/51. Second edition of Vol. 1, 1956.

A Prakrit work (with a few later interpolations) on cosmography belonging to the Digambara sect of the Jaina religion. Contains various formulas for mensuration and mathematical series. See T. A. Sarasvati's article, item 1536.

1478. Kamalākara. *Siddhāntatattvaviveka.* (A.D. 1658). Edited by Sudhākara Dvivedin. (Benares Sanskrit Series No. 1, No. 2, No. 3, No. 6, and No. 14.) Benares: Braj Bhushan Das & Co., 1880–1885. Revised by Muralīdhara Jhā, 1924–1935. In Sanskrit.

An astronomical work. No modern translation available. For a study of its trigonometric formulas, see R. C. Gupta, "Sines of Sub-Multiple Arcs as Found in the *Siddhāntatattvaviveka*", *Ranchi University Mathematical*

Journal 5 (1974), 21–27, and "Sines and Cosines of Multiple Arcs as Given by Kamalākara", *Indian Journal of History of Science* 9 (1974), 143–150.

1479. Mahāvīra (d. ca. 480 B.C.). *Jaṃbuddīvapaṇṇattī.* Edited by Shobhachandra Bharill, et al. *Sixth Upānga: Jambuddīvapannnattisuttam.* (Jināgama Granthamālā 26.) Beawar: Sri Agam Prakashan Samiti, 1986.

A geographical work in Ardhamāgadhī ascribed to the founder of the Jaina religion. With a Hindi translation and notes by Chhaganlal Shastri.

1480. Mahāvīra (ca. A.D. 850). *Gaṇitasārasaṅgraha.* Edited by M. Raṅgācārya. Madras: Government Press, 1912. Also edited by Lakṣmīcandra Jain. (Jīvarāja Jaina Granthamālā 12.) Sholapur: Jaina Saṃskṛti Saṃrakshaka Saṃgha, 1963. In Sanskrit.

A voluminous work on arithmetic and mensuration (pāṭī) by a Jaina mathematician. Raṅgācārya's edition contains an English translation while Jain's edition has a Hindi translation. For a discussion on Mahāvīra's contribution see B. S. Jain's article, "On the *Gaṇitasārasaṃgraha* of Mahāvīra (c. A. D. 850)" *Indian Journal of History of Science* 12 (1977), 17–32.

1481. Nārāyaṇa Paṇḍita (fl. 1356). *Bījagaṇitāvataṃsa.* Edited by Kripa Shankar Shukla. "Nārāyaṇa Paṇḍita's Bījagaṇitāvataṁsa: Part I", *Ṛtam* 1 (2), supplement, 1969/70.Reprinted Lucknow: Akhila Bharatiya Sanskrit Parishad, 1970. In Sanskrit.

A book on algebra (bījagaṇita). The edition is based on a unique, incomplete manuscript, which contains the first (introductory) part and the beginning of the second (main) part. For a study, see B. Datta, "The Algebra of Nārāyaṇa" *Isis* 19 (1933), 472–485.

1482. Nārāyaṇa Paṇḍita. *Gaṇitakaumudī.* (A.D. 1356). Edited by Padmākara Dvivedi. (The Princess of Wales Saraswati Bhavana Texts No. 57.) Benares: Government Sanskrit Library, 1936 (part 1); 1942 (part 2). In Sanskrit.

A book on arithmetic and mensuration (pāṭī) in 14 chapters. Chapters 13 (on aṅkapāśa) and 14 (on bhadragaṇita) have been newly edited with English translation and mathematical commentary by Takanori Kusuba in his dissertation (Brown University), "Combinatorics and Magic Squares in India: A Study of Nārāyaṇa Paṇḍita's *Gaṇitakaumudī*, Chapters 13 and 14", Ann Arbor: University Microfilms International, 1993. For a study of Chapter 13, see P. Singh, item 1550. For studies of Chapter 14, see S. Cammann, item 1573 and T. Hayashi, item 1551.

1483. Nīlakaṇṭha Somastuvan (b. A.D. 1444, d. after 1542). *Āryabhaṭīyabhāṣya* (ca. 1510). Edited in three parts: Parts 1 and 2 by K. Sāmbaśiva Śāstrī and part 3 by S. Kunjan Pillai. *The Āryabhaṭīya of Āryabhaṭācārya with the Bhāṣya of Nīlakaṇṭha Somastuvan.* Part 1:

Gaṇitapāda, part 2: Kālakriyāpāda, part 3: Golapāda. (Trivandrum Sanskrit Series 101, 110, 185.) Trivandrum: Government Press, 1930, 1931, 1957. In Sanskrit.

Commentary on the *Āryabhaṭīya* of Āryabhaṭa I. Full of mathematical inspiration, it suggests original interpretations of some of Āryabhaṭa's mathematical and astronomical rules; some of them, at least, are better than his predecessors' linguistically as well as mathematically. See Hayashi's "Āryabhaṭa's Rule and Table for Sine-Differences", item 1565.

1484. Nīlakaṇṭha Somastuvan. *Tantrasaṅgraha.* (A.D. 1501). Edited by K. Venkateswara Sarma. (Panjab University Indological Series No. 10.) Hoshiarpur: Panjab University, 1977. In Sanskrit.

An astronomical work in 8 chapters written by an ingenious mathematician and astronomer belonging to the Mādhava's academic lineage. With editor's introduction and two commentaries, the *Yuktidīpikā* (on the first 4 chapters) and *Laghuvivṛti* (on the rest), of Śaṅkara Vāriyar. Sarma's edition, without the commentaries, has been reproduced with Narasimhan's English translation and with an introduction by both in: K. V. Sarma and V. S. Narasimhan, "*Tantrasaṃgraha* of Nīlakaṇṭha Somayāji", *Indian Journal of History of Science* 33 (1998), (1), S1–S48; (2), S49–S90; and (3), S91–146. Śaṅkara's *Yuktidīpikā* is based on Jyeṣṭhadeva's *Yuktibhāṣā* in Malayalam, for the contents of which see K. Venkateswara Sarma and S. Hariharan, "*Yuktibhāṣā* of Jyeṣṭhadeva: A Book of Rationales in Indian Mathematics and Astronomy — An Analytical Appraisal", *Indian Journal of History of Science* 26 (1991), 185–207.

1485. Śaṅkara, Vāriyar and Nārāyaṇa. *Kriyākramakarī* (ca. 1550). In Sanskrit.

Commentary on the *Līlāvatī*. See Bhāskara II's *Līlāvatī*, item 1473. Informative with a number of citations from earlier works, some of which are otherwise unknown to us. More than 80 percent of the commentary (on verses 1–199) was composed by Śaṅkara (ca. 1540) and the rest (on verses 200–272) by Nārāyaṇa (ca. 1550). No English translation available. For a partial Japanese translation see Hayashi, et al., *Indo sūgaku kenkyū*, item 1566. For recent studies of its contents see also the works of Gupta (item 1500), of Hayashi and Kusuba (item 1557), of Mukhopadhyay and Adhikari (item 1567), and of Sarasvati (item 1547).

1486. Sphujidhvaja. *Yavanajātaka* (A.D. 269/270). Edited by David Pingree. *The Yavanajātaka of Sphujidhvaja.* Vols. 1 and 2. (Harvard Oriental Series vol. 48.) Cambridge: Harvard University Press, 1978. In Sanskrit.

An astrological work. Text with English translation and a study. A luni-solar calendar based on a yuga (period) of 165 years is discussed in the last chapter, where occur numerical expressions by words based on the decimal place-value system. For a different interpretation of the passages related to the yuga system, see Kripa Shankar Shukla, "The Yuga of the *Yavanajātaka*: David Pingree's Text and Translation Reviewed", *Indian Journal of History of Science* 24 (1989), 211–223.

1487. Śrīdhara (8th century). *Gaṇitapañcaviṃśī*. Edited by David Pingree in "The *Gaṇitapañcaviṃśī* of Śrīdhara", *Ṛtam: Ludwik Sternbach Felicitation Volume* Lucknow: Akhila Bharatiya Sanskrit Parishad, 1979, 887–909. In Sanskrit.

A small work on arithmetic and mensuration (pāṭī), which is claimed to be an epitome of a larger work of the same author. The editor points out in the introduction that the date of Śrīdhara is fixed between Brahmagupta (fl. A.D. 628) and Govindasvāmin (fl. A.D. 800/850). The text, which has been edited from a unique, incomplete manuscript (53 verses are extant), contains later interpolations. See T. Hayashi, "Śrīdhara's Authorship of the Mathematical Treatise *Gaṇitapañcaviṃśī*", *Historia Scientiarum* 4 (1995), 233–250. No translation is available, but see the same article for a list of the contents.

1488. Śrīdhara. *Pāṭīgaṇita*. Edited by Kripa Shankar Shukla. Lucknow: Lucknow University, 1959. In Sanskrit.

A full-scale work on arithmetic and mensuration (pāṭī). Edited with an old anonymous commentary preserved in a unique, incomplete manuscript and with an English translation. The extant text contains rules and examples for various topics of pāṭīgaṇita (up to the middle of the section on plane figures) in 251 verses.

1489. Śrīdhara. *Triśatikā*. Edited by Sudhākara Dvivedin. Benares: Chandraprabha Press, 1899. In Sanskrit.

A small work on arithmetic and mensuration (pāṭī) in 180 verses, which is claimed to be an epitome of a larger work of the same author. For its partial English translation, see Ramanujacharia and G. R. Kaye, "The *Triśatikā* of Śrīdharācārya", *Bibliotheca Mathematica* 3 (13) (1912–1913), 203–217.

1490. Śrīpati (fl. 1040). *Gaṇitatilaka*. Edited by Hīralāl R. Kāpadīā. (Gaekwad's Oriental Series No. 78.) Baroda: Oriental Institute, 1937. In Sanskrit.

A work on arithmetic and mensuration (vyaktagaṇita). Edited with the commentary of Siṃhatilakasūri based on a unique, incomplete manuscript (up to the middle of the section on mixture in about 125 verses). In the introduction the editor surveys mathematical topics dealt with in non-mathematical literature of the Jaina religion. For an English translation, see Kripa Nath Sinha, "Śrīpati's *Gaṇitatilaka*: English Translation with Introduction", *Gaṇita Bhāratī* 4 (1982), 112–133.

1491. Śrīpati. *Siddhāntaśekhara.* Edited by B. Miśra. Calcutta: University of Calcutta, 1932 (part 1) 1947 (part 2). In Sanskrit.

An astronomical work, which contains two chapters on mathematics. Edited with the commentaries of Makkibhaṭṭa (in chapters 1–4) and of the editor (in chapters 5–20) and an introduction by N. K. Majumdar. For English translations of Chapters 13 (on arithmetic and mensuration) and 14 (on algebra), see respectively Kripa Nath Sinha, "Vyaktagaṇitādhyāya of Śrīpati's *Siddhāntaśekhara* (English Translation with Introduction)", *Gaṇita Bhāratī* 10 (1988), 40–50, and Kripa Nath Sinha, "Algebra of Śrīpati: An Eleventh Century Indian Mathematician (Translation of avyaktagaṇitādhyāya of *Siddhāntaśekhara*)", *Gaṇita Bhāratī* 8 (1986), 27–34. See also Kripa Nath Sinha, "Śrīpati: an 11th-Century Indian Mathematician", *Historia Mathematica* 12 (1985), 25–44.

1492. *Śulbasūtra* (6th century B.C. and later). Edited by S. N. Sen and A. K. Bag, *The Śulbasūtras of Baudhāyana, Āpastamba, Kātyāyana and Mānava with Text, English Translation and Commentary.* New Delhi: Indian National Science Academy, 1983. In Sanskrit.

The editions of the texts in this work are based on the editions published before separately by A. Bürk, W. Caland, G. S. Nene, M. M. Paṭhaka, G. Thibaut, and by J. M. van Gelder, as well as on several new manuscripts for each. With a moderate length of bibliography. See A. Michaels, item 1526, for more bibliographical information.

1493. Ṭhakkura Pherū (fl. 1315). *Gaṇitasāra.*Edited in Agaracanda and Bhaṃvaralāla Nāhaṭā, *Ratnaparīkṣādisaptagranthasaṅgraha*, (Rājasthāna Purātana Granthamālā 44 parts 1 and 2.) Jodhpur: Rājasthāna Prācyavidyā Pratiṣṭhāna, 1961, part 2, 41–74.

A Prakrit work on arithmetic and mensuration (pāṭī). Consists of 45 "gates" (dvāras) divided in 4 chapters. The first 3 chapters deal with traditional topics of pāṭī, while the last one contains new or rare topics, including the oldest extant mathematical treatment of magic squares in India. For the last topic see T. Hayashi's article, "Hojinzan", item 1551.

1494. Varāhamihira (fl. 550). *Pañcasiddhāntikā.* Edited by Otto Neugebauer and David Pingree. *The Pañcasiddhāntikā of Varāhamihira.* Copenhagen: Munksgaard, 1970. Also edited by K. Venkateswara Sarma, Madras: P. P. S. T. Foundation, 1993. In Sanskrit.

Consists of compendia of the texts of five old astronomical schools. The former edition, by Pingree, is accompanied by an English translation by Pingree and a mathematical commentary by Neugebauer and Pingree, and the latter by an English translation and notes by T. S. Kuppanna Sastry.

1495. Vīrasena. *Dhavalāṭīkā* (A.D. 781). Edited by H. L. Jain, et al., *Ṣaṭkhaṇḍāgama of Puṣpadanta and Bhūtabali with the Commentary Dhavalā of Vīrasena*. Amaraoti, 1940–58. 16 volumes. Reprinted. Sholapur: Jaina Saṃmskṛti Saṃrakshaka Saṃgha, 1980–1984.

A Prakrit commentary on a canonical work of the Jaina Digambara sect. With a Hindi translation. Vīrasena's commentary contains a number of mathematical passages. Vol. 4 is accompanied by A. N. Singh's article, "Mathematics of *Dhavalā*", in both English (1–24) and Hindi (1–28). See also A. N. Singh's article, item 1537 and T. Hayashi, "Geometric Formulas in the *Dhavalā* of Vīrasena (780 C. E.)", *Jinamanjari* 14 (2) (1996), 53–76.

General Histories

1496. Bag, Amulya Kumar. *Mathematics in Ancient and Medieval India*. Varanasi: Chaukhambha Orientalia, 1979.

Chapter 1 provides biographical and bibliographical information about mathematicians chronologically, and the remaining 6 chapters treat the following topics in order: arithmetic, geometry, algebra, trigonometry, infinitesimal calculus, and Indo-Persian/Arabic literature on mathematics. With a select bibliography.

1497. Billard, Roger. *L'astronomie indienne: investigation des textes Sanskrits et des données numériques*. Paris: École Française d'Extrême Orient, 1971.

Mainly consists of mathematical analyses (by means of modern techniques such as the least-square method) of the numerical data used in various Sanskrit astronomical works, and conjectures that those data have been obtained according to the observations made by the Indian astronomers. One of the remarkable results the author has obtained is the date of the *Mahāsiddhānta* of Āryabhaṭa II. It is usually assigned before Bhāskara II (b. A.D. 1114) on the basis of the textual relationships, but he has moved it forward to ca. 1500. For the controversial date, see David Pingree, "On the Date of the *Mahāsiddhānta* of the Second Āryabhaṭa", *Gaṇita Bhāratī* 14 (1992), 55–56, and Raymond Mercier, "The Date of the *Mahāsiddhānta*", *Gaṇita Bhāratī* 15 (1993), 1–13. For reviews in favor of Billard see B. L. van der Waerden, "A Summary of Roger Billard's *L'Astronomie indienne*", *Gaṇita Bhāratī* 10 (1988), 21–30, and S. N. Sen's article, "Survey of Studies in European Languages", in *History of Astronomy in India*, item 1509.

1498. Chattopadhyaya, Debiprasad, ed. *Studies in the History of Science in India*. New Delhi: Editorial Enterprises (distributed by Asha Jyoti, New Delhi), 1992. 2 vols.

Consists of reprints of articles written by classical authorities on Indology such as al-Bīrūnī, H. T. Colebrooke, Th. Stcherbatsky, H. Jacobi, A. F. R. Hoernle, H. Kern, G. Thibaut, G. Bühler, B. Datta,

J. Filliozat, etc., most of whom flourished in the 19th century and in the first half of the 20th century. Vol. 1 contains articles on philosophy and science, on medicine, and on alchemy, chemistry, botany, etc.; Vol. 2 on astrology, astronomy and mathematics, and on interaction and exchange. Some of them are still useful. See items 1531, 1533, 1554.

1499. Datta, Bibhutibhusan, and Avadesh Narayan Singh. *History of Hindu Mathematics: A Source Book*. Vol. 1. *Numerical Notation and Arithmetic*. Vol. 2. *Algebra*. Lahore: Motilal Banarsidass, 1935/1938. Reprinted in one vol. Bombay: Asia Publishing House, 1962.

Written sixty years ago, this work remains one of the most informative works on Indian mathematics, although their dating of the Vedic and post-Vedic literature (the *Vedas* to ca. 3,000 B.C., the *Brāhmaṇas* to ca. 2,000 B.C., the *Vedāṅgajyotiṣa* to ca. 1,200 B.C., Pāṇini to the 8th century, etc.) has to be revised by taking about two fifths of the number for each date. Eight of the authors' joint works that treat other topics have been posthumously published, with revisions, by K. S. Shukla in *Indian Journal of History of Science*: "Hindu Geometry", 15 (1980), 121–188; "Hindu Trigonometry", 18 (1983), 39–108; "Use of Calculus in Hindu Mathematics", 19 (1984), 95–104; "Magic Squares in India", 27 (1992), 51–120; "Use of Permutations and Combinations in India", 27 (1992), 231–249; "Use of Series in India", 28 (1993), 103–129; "Surds in Hindu Mathematics", 28 (1993), 253–264; and "Approximate Values of Surds in Hindu Mathematics", 28 (1993), 265–275.

1500. Gupta, Radha Charan. "South Indian Achievements in Medieval Mathematics". *Gaṇita Bhāratī* 9 (1987), 15–40.

Gives a well-documented survey of medieval (12th–17th centuries) South Indian mathematics according to topics: decimal place-value names, geometrical algebra, algebraic normal forms, cyclic quadrilaterals, approximations to π and series for it, sine tables and various formulas in trigonometry including the Mādhava-Gregory series.

1501. Hayashi, Takao. *Indo no sūgaku* (†Indian Mathematics†.) Tokyo: Chūō kōronsha, 1993.

A history of Indian mathematics from the Vedic times to the 17th century. Divided into 8 chapters: Numeral Notations and Invention of Zero, *Śulbasūtra* (Mathematics of Altars), Society and Mathematics, Jaina Mathematics, Mathematics of Āryabhaṭa I, Establishment of the Basic Framework of Indian Mathematics, Later Developments, and Cultural Exchange and Mathematics. See also Hayashi's articles, "Indian Mathematics", *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, edited by I. Grattan-Guinness, (London: Routledge, 1994), Vol. 1, 118–130; and "Mathematics in the Vedic Texts", "Śulbasūtras", and "Gaṇita" to be included, respectively as

Chapters 5, 10.a.1, and 27.a, in *Indian Science*, Vol. 6 of the *History of Science*, Roma: Istituto della Enciclopedia Italiana.

1502. Joseph, George Gheverghese. *The Crest of the Peacock: Non-European Roots of Mathematics*. London: Penguin Books, 1990. Reprinted New Delhi: Affiliated East-West Press Pvt. Ltd., 1995.

Provides a well-balanced picture of the history of mathematics in non-Western cultural areas (South America, Egypt, Mesopotamia, China, India, and the Islamic world) in 10 chapters. Two chapters are devoted to Indian mathematics. Chapter 8 (Ancient Indian Mathematics) treats measurements in Indus Valley Civilization, mathematics from the *Veda* and *Śulbasūtras*, numeral notations, Jaina mathematics, and the *Bakhshālī Manuscript*, and Chapter 9 (Indian Mathematics: The Classical Period and After) contains biographies of major mathematicians and descriptions of Indian achievements in mathematics according to topics: algebra, trigonometry, Kerala mathematics (Mādhava, etc.), and other notable contributions (geometric representation of arithmetic progressions, cyclic quadrilaterals, etc.).

1503. Juschkewitsch, A. P. *Geschichte der Mathematik in Mittelalter*. Leipzig: Teubner, 1964. Translated from the 2nd edition of the Russian original by V. Ziegler.

Treats in order the mathematics of China, India, the Islamic world, and of medieval Europe. Chapter 2 on Indian mathematics, though based mainly on secondary sources, provides a fair picture of the subject according to topics: the *Śulbasūtras*, the origin of the decimal place-value system, arithmetical operations, fractions, extraction of roots, the proof by nine, the rule of three, the rule of false position, symbolism in algebra, negative and irrational numbers, linear and quadratic equations, indeterminate equations, mathematical series, combinations, geometry, trigonometry, and calculation of π and power series for arctangent.

1504. Kuppuram, G., and K. Kumudamani eds. *History of Science and Technology in India*. Delhi: Sundeep Prakashan, 1990. 12 vols.

Vol. 2 entitled *Mathematics and Astronomy* and Vol. 4 *Science* contain many articles on Indian mathematics reprinted from various journals, including those of K. V. Sarma and of A. K. Bag, and a few original ones, including M. D. Srinivas's article, item 1510.

1505. Ōhashi, Yukio. "Astronomical Instruments in Classical Siddhāntas". *Indian Journal of History of Science* 29 (1994), 155–313.

Traces the development of the astronomical instruments described in the major astronomical works, from Āryabhaṭa I (5th century) to Bhāskara II (12th century). Mostly consists of extracts from Sanskrit works with English translations and mathematical commentaries about them. See also Ōhashi's articles, "Development of Astronomical Observation in Vedic and Post-Vedic India", *Indian Journal of History of*

Science 28 (1993), 185–251; "Early History of the Astrolabe in India", *Indian Journal of History of Science* 32 (1997), 199–295.

1506. Pingree, David. "History of Mathematical Astronomy in India". In *Dictionary of Scientific Biography.* Vol. 15. Edited by C. C. Gillispie. New York: Charles Scribner's Sons, 1978, 533–633. Reprinted, 1981.

A monumental work that traces the roots and describes the development of the subject with special attention on its transmission from other civilizations to India. Divided into 11 sections (excluding the introduction, conclusions and epilogue): Vedic astronomy (various time periods and stars), Babylonian astronomy in India (calendaric elements in the *Vedāṅgajyotiṣa*, etc.), Greco-Babylonian astronomy in India (the *Yavanajātaka* and the *Pañcasiddhāntikā*), cosmology (the *Purāṇas* and the Jaina canonical works), mathematical astronomy of five pakṣas (schools) influenced by Greek astronomy and their derivatives, that is, Brāhma-pakṣa (the *Paitāmahasiddhānta*, *Brāhmasphuṭasiddhānta*, etc.), Ārya-pakṣa (the *Āryabhaṭīya*, etc.), Ārdharātrika-pakṣa (Lāṭadeva's *Sūryasiddhānta*, the *Khaṇḍakhādyaka*, etc.), Saura-pakṣa (the *Sūryasiddhānta*, etc.), eclectic astronomers (Muñjāla, Āryabhaṭa II, Nīlakaṇṭha), and Gaṇeśa-pakṣa (the *Grahalāghava*), and Islamic astronomy in India (the *Yantrarāja*, etc.). The essence of this work has been newly formulated together with illustrations from several Sanskrit manuscripts of the 18th and the 19th centuries as "Astronomy in India", *Astronomy before the Telescope*, edited by Christopher Walker, London: British Museum Press, 1996, 123–142. For the last topic (Islamic astronomy in India) see also the Pingree's articles, "Islamic Astronomy in Sanskrit", *Journal of the History of Arabic Science* 2 (1978), 315–330; and "Indian Reception of Muslim Versions of Ptolemaic Astronomy", *Tradition, Transmission, Transformation: Proceedings of Two Conferences on Pre-modern Science Held at the University of Oklahoma*, edited by F. Jamil Ragep and Sally P. Ragep with Steven Livesey, Leiden, New York, Köln: E. J. Brill, 1996, 471–485.

1507. Sen, Samarendra Nath. "Mathematics". In *A Concise History of Science in India.* Edited by D. M. Bose, S. N. Sen, B. V. Subbarayappa. New Delhi: Indian National Science Academy, 1971, 136–212.

This article, which is the 3rd chapter of the book, gives a balanced picture of Indian mathematics, describing metrology in the Indus Civilization, mathematical knowledge in the Vedic and Śulba texts, Jaina mathematics, mathematics of the periods from the 2nd to the 18th centuries (according to topics as well as to sources), Arabic and Persian mathematics in India, and transmission. The 2nd chapter, "Astronomy", also by Sen is recommended as an introduction to Indian mathematical astronomy.

1508. Sen, Samarendra Nath, and Amulya Kumar Bag. "Post-Vedic Mathematics". In the science and technology volume (vol. 6) of *The*

Cultural Heritage of India. Edited by Priyadaranjan Ray and S. N. Sen. Calcutta: Ramakrishna Mission Institute of Culture, 1986, 36–55.

A sketch of the major achievements of Indian mathematics from a few centuries before the Christian era to the 18th century. Divided in 5 sections: arithmetic (with numeral notations), algebra (with combinatorics), geometry, trigonometry, and calculus.

1509. Sen, Samarendra Nath, and Kripa Shankar Shukla, eds. *History of Astronomy in India*. New Delhi: Indian National Science Academy, 1985.

Consists of 13 articles by experts on various aspects of Indian astronomy such as: a survey of source materials, the zīj literature in India, a survey of studies by European scholars, astronomy in Indus Civilization and during Vedic times, post-Vedic astronomy, the yuga system and the mean and true longitudes, eclipses, parallax, precession, phases of the moon, heliacal rising and setting, conjunctions, calendar, instruments, observatories, introduction of modern Western astronomy, and astronomy in the 20th century.

1510. Srinivas, M. D. "The Methodology of Indian Mathematics and Its Contemporary Relevance". In *History of Science and Technology in India*. Edited by G. Kuppuram and K. Kumudamani, eds., Vol. 2, 29–86. See item 1504 for further bibliographic details.

Analyzes the structure of the upapatti (derivations) and yukti (reason or rationales) of mathematical rules given by Gaṇeśa and Kṛṣṇa in their respective commentaries on Bhāskara II's works (see items 1472 and 1473), and discusses the treatment of numbers (saṃkhyā) by the Nyāya-Vaiśeṣika school of philosophy. A list of 17 commentaries, which contain upapatti or yukti, and a translation of the yukti given by Kṛṣṇa to the kuṭṭaka rules (for linear indeterminate equations) of Bhāskara II are appended.

1511. Srinivasiengar, C. N. *The History of Ancient Indian Mathematics*. Calcutta: The World Press, 1967.

Describes various aspects of Indian mathematics chronologically in 12 chapters except for Chapters 9 to 11 where special topics are treated: 1. The Decimal System of Numeration, 2. The *Śulba Sūtras*, 3. The Mathematics of the Jainas, 4. The *Bakhshālī Manuscript*, 5. Āryabhaṭa, 6. Brahmagupta, 7. Mahāvīrācārya, 8. Bhāskara II, 9. Kuṭṭaka, 10. Vargaprakṛti or the Equation of the Multipled Square, 11. Miscellaneous Equations, 12. Indian Mathematics after Bhāskara II (mainly on the Kerala mathematics).

Number Expression

1512. Bronkhorst, Johannes. "A Note on Zero and the Numerical Place-Value System in Ancient India". *Asiatische Studien* 48 (4) 1994, 1039–1042.

Points out that mention is made of a place-value system of numeral notation in the Chinese translations of some Buddhist texts originally composed in the early centuries of the Christian era.

1513. Datta, Bibhutibhusan. "Early Literary Evidence of the Use of Zero in India". *American Mathematical Monthly* 33 (1926), 449–454.

Points out the use of, and references to, zero in early Sanskrit works including Varāhamihira's *Pañcasiddhāntikā*.

1514. Ganguli, Saradakanta. "The Indian Origin of the Modern Place-Value Arithmetical Notation". *American Mathematical Monthly* 39 (1932), 251–256, 389–393; 40 (1933), 25–31, 154–157.

A close examination of both mathematical and non-mathematical literatures as well as of inscriptions.

1515. Gupta, Radha Charan. "Who Invented the Zero?" *Gaṇita Bhāratī* 17 (1995), 45–61.

Surveys and discusses the history of the zero in Egypt, Babylonia, Greece, China, Maya, and India mainly according to four categories of zero, that is, emptiness in general, the starting point of reckoning or measuring, a symbol indicating a vacant place in any place-value notation of numbers, and a number.

1516. Ifrah, Georges. *Histoire universelle des chiffres*. Paris: 'Edition Segher, 1981. Translated into English by Lowell Bair as *From One to Zero: A Universal History of Numbers*, New York: Penguin Books, 1985.

Consists of 30 chapters divided in 6 parts: Awareness of Numbers, Concrete Counting, The Invention of Numerals, Numerals and Letters, Hybrid Numeration Systems, and The Ultimate Stage of Numeral Notation. The last, 30th (29th in the English translation) chapter entitled "The Origin of the Hindu-Arabic Numerals" contains a good account of the development of numerals and other number expressions in India and of the transmission of the Indian place-value notation to the Islamic world and to Europe. With a number of illustrations including calligraphy.

1517. Indraji, Bhagavanlal. "On Ancient Nágarí Numeration; from an Inscription at Nánegháṭ". *Journal of the Bombay Branch of the Royal Asiatic Society* 12 (1876), 404–406.

Describes and analyzes the Brāhmī, non-place-value, numerical figures which occur nearly 30 times in a list of gifts made on an occasion of religious rites recorded in a cave inscription of Nānāghāṭ assignable to the 1st century B.C. With a table of the numerical figures.

1518. Pandit, M. D. *Zero in Pāṇini.* (Publication of the Centre of Advanced Study in Sanskrit, Class B, No. 12.) Pune: University of Poona, 1990.

What is called "zero" in this work is the concept of dropping or disappearance (lopa) in a wide sense used as grammatical techniques by Pāṇini (4th century B.C.) in his book of a descriptive grammar of the Sanskrit language, *Aṣṭādhyāyī.* Classifying various kinds of "dropping" under three categories, the author describes them in detail in the first 3 chapters and tries to trace their origins in the next 3 chapters. The three categories are: the dropping of linguistic elements (a sound or sound group), that of the consonants which have been artificially attached to grammatical elements in order to indicate their functions symbolically, and omission of a word or words in rules in order to avoid repetition. The *Aṣṭādhyāyī* is often compared with the *Elements* of Euclid because of its deductive system and of its influence upon the scientific and philosophic traditions in India. See Frits Staal's article, "Euclid and Pāṇini", *Philosophy East and West* 15 (1965), 99–116, reprinted in his book, *Universals: Studies in Indian Logic and Linguistics*, Chicago and London: The University of Chicago Press, 1988, 143–160.

1519. Raman, Anand V. "The Katapayadi Formula and the Modern Hashing Technique". *Annals of the History of Computing* 19 (4) 1997, 49–52.

Analyzes the kaṭapayādi notation of numbers used in South Indian musicology in the 18th century from the view point of the computer hashing technique for the data storing. For the kaṭapayādi notation see Datta and Singh, item 1499, Vol. 1, 69–72.

1520. Ruegg, D. S. "Mathematical and Linguistic Models in Indian Thought: The Case of Zero and śūnyatā". *Wiener Zeitschrift für die Kunde Südasiens* 22 (1978), 171–181.

Points out that the *Abhidharmakośabhāṣya* of Vasubandhu, a Buddhist philosopher of the 4th or the 5th century A.D., contains a teaching of Vasumitra assignable to the 1st or 2nd century A.D., which refers to a kind of abacus based on the decimal place-value system with counters (vartikās).

Vedic Mathematics and Śulbasūtras

1521. Datta, Bibhutibhusan. *The Science of the Śulba: A Study in Early Hindu Geometry.* Calcutta: University of Calcutta, 1932.

A classical work on the subject, which is still useful as a mine of basic information on the *Śulbasūtras.* The topics divided into 16 chapters are: Śulba texts, commentaries on them, relationships with Vedic literature, "postulates" presupposed by Śulba authors, constructions, combination of areas, transformation of areas, areas and volumes, Pythagorean theorem, rational rectangles, squaring the circle, similar figures, geometrical algebra, indeterminate problems, elementary treatment of surds, and fractions and other minor matters.

1522. Datta, Bibhutibhusan. "Vedic Mathematics". Revised anonymously. In the science and technology volume (vol. 6) of *The Cultural Heritage of India*. Edited by Priyadaranjan Ray and S. N. Sen. Calcutta: The Ramakrishna Mission Institute of Culture, 1986 (reprinted 1991), 18–35.

A survey of mathematical knowledge scattered in the Vedic literature. Divided in 3 sections: astronomy, geometry (mostly from the *Śulbasūtras*), and arithmetic.

1523. Hopkins, Edward Washburn. "Numerical Formulae in the Veda and Their Bearing on Vedic Criticism". *Journal of the American Oriental Society* 16 (1894), 275–281.

Survey and analysis of numerical expressions in the *Ṛgveda*.

1524. Khadilkar, S. D. *Kātyāyana Śulba Sūtra.* Poona: Vaidika Saṃśodhana Maṇḍala, 1974.

Divided in two sections. Section I contains text, English translation, and explanatory notes, and Section II articles related to the *Kātyāyana Śulbasūtra.*

1525. Kulkarṇī, Raghunātha Puruṣottama. *Geometry According to Śulba Sūtra.* Poona: Vaidika Saṃśodhana Maṇḍala, 1983.

The topics divided into 12 chapters are: geometry of Indus Civilization (conjectures based on archaeological findings), geometry before the *Śulbasūtras* (in Vedic literature), arithmetic background (in Vedic and Śulba literature), linear measures in the *Śulbasūtras*, constructions, areas and volumes, location of dakṣiṇāgni (a fire altar), similar figures, Pythagorean theorem, rational right-angled triangles, $\sqrt{2}$ and π, and summary. A glossary of geometrical terms and a list of bricks used for altars with their sizes are appended. See also the following works by Kulkarṇī: *Layout and Construction of Cities according to Baudhāyana-, Mānava-, and Āpastamba-Śulbasūtras*, (Bhandarakar Oriental Research Institute Research Unit Series 10), Poona: Bhandarkar Oriental Research Institute, 1987; *Layout for Different Sacrifices according to Different Śrauta Sūtras*, Ujjain: Maharshi Sandipani Rashtriya Veda Vidya Pratishthan, 1997.

1526. Michaels, Axel. *Beweisverfahren in der Vedischen Sakralgeometrie.* (Alt- und Neu-Indische Studien [Universität Hamburg] No. 20.) Wiesbaden: Franz Steiner Verlag GmbH, 1978.

A study of the historical conditions which brought about the development of Vedic geometry. The topics divided into 3 chapters are: Introduction (theoretical foundation of science, introduction to Vedic ritual geometry), Determination and Reconstruction of Proof-Procedure (from pre-geometric vocabulary to basic terminology of geometry, proof-procedure based on geometrico-arithmetical brick-operations, proof-procedure based on symmetry and equality of area, problem of irrationality), and Linguistic Explanation of Important Concepts (aṅgula, caturasra, nirañcana, śulva, saviśeṣa, spandyā). According to the author, Vedic geometry embodied in the *Śulbasūtras* is logic-free and non-axiomatic, but provable, and the proofs are given in the texts "by a demonstration of the appropriate patterns of action." Useful appendices: concordances of the editions of *Śulbasūtras* and of the *Śulbasūtras* themselves and an extensive bibliography. See also item 1527.

1527. Michaels, Axel. *A Comprehensive Śulvasūtra Word Index.* (Alt- und Neu-Indische Studien [Universität Hamburg] No. 24.) Wiesbaden: Franz Steiner Verlag GmbH, 1983.

Word index of the four major *Śulbasūtras*: *Āpastamba-* edited by A. Bürk, *Baudhāyana-* by G. Thibaut, *Kātyāyana-* by S. D. Khadilkar, and *Mānava-* by J. M. van Gelder.

1528. Satya Prakash. *Geometry in Ancient India.* Delhi: Govindram Hasanand, 1987.

Treats the Śulba geometry and its background in 7 chapters: Foundations of Geometry in the Middle East (a summary of the geometries in ancient Egypt and Greece), Geometry in the Vedic period (a survey of basic geometrical terms used in the *Vedas*), The *Brāhmaṇas* Lay the Foundations of Mensuration and Geometry (a survey of passages related to measurements and drawings in the *Brāhmaṇa* literature), Thibaut on the *Śulbasūtras* (reprint of G. Thibaut's article, item 1531), Fire-Altars I: Simple Fire-Altars (descriptions of the square, oblong, circular, triangular, and rhombus altars according to the *Śulbasūtras*), Fire-Altars II: Various Śyena-Shaped Altars (descriptions of the altars shaped like birds with wings spread including the śyena or falcon, according to the *Śulbasūtras*), Fire-Altars III: Diagrams and Sketches (diagrams showing the arrangements of bricks for the fire-altars treated in the foregoing two chapters, and ground plans for the ritual sites). Most of the figures in the last chapter have been reprinted from N. K. Majumdar's article, "Sacrificial Altars: Vedis and Agnis", *The Journal of the Indian Society of Oriental Art* 8 (1940), 21–40.

1529. Seidenberg, A. "The Ritual Origin of Geometry". *Archive for History of Exact Sciences* 1 (1962), 488–527.

Seidenberg's main thesis is that the elements of geometry in ancient Greece, Babylonia, Egypt, India, and China are derived from a system of ritual practices as disclosed in the *Śulbasūtras*. See also his article, "The Origin of Mathematics", *Archive for History of Exact Sciences* 18 (1978), 301–342.

1530. Staal, Frits, ed. *Agni: The Vedic Ritual of the Fire Altar.* Vols. 1 and 2. Berkeley: Asian Humanities Press, 1983.

An extensive study of a Vedic ritual called agnicayana ("piling of bricks for the fire altar"). Divided into 5 parts (excluding the introduction): the Agnicayana Ritual, the 1975 Performance (a record, with a number of photographs, of an agnicayana rite performed at Kerala in April, 1975), Perspectives (22 articles on various aspects of agnicayana, including one on the *Śulbasūtras* by A. L. Seidenberg, "The Geometry of the Vedic Rituals", Vol. 2, 95–126), Texts and Translations (relevant passages from a *Brāhmaṇa* and two *Śrautasūtras*), and Films, Tapes, and Cassettes (recording data of the ones produced during the 1975 performance). With a glossary-index.

1531. Thibaut, George Frederick. "On the Śulva-sūtras". *Journal of the Asiatic Society of Bengal* 44 (1875), 227–275. Reprinted Calcutta: C. B. Lewis, Baptist Mission Press, 1875. Also reprinted in Debiprasad Chattopadhyaya, ed., *Mathematics in the Making in Ancient India.* Calcutta and Delhi: K P Bagchi & Co., 1984, 1–66; in the same editor's *Studies*, item 1498, Vol. 2, 415–478; and as Chapter 4 (pp. 100–157) of Satya Prakash's work, *Geometry in Ancient India*, item 1528.

A pioneering work on *Śulbasūtras*, which is still informative and useful. The first reprint by Chattopadhyaya is coupled with Thibaut's English translation of the *Baudhāyana Śulbasūtra* (originally published in *The Paṇḍit* 9, 1874/75; 10, 1875/76; and NS 1, 1876/77) and headed by his own introduction.

1532. Tīrthaji, Bhāratī Kṛṣṇa. *Vedic Mathematics or Sixteen Simple Mathematical Formulae from the Vedas.* Delhi: Motilal Banarssidass, 1965.

Reprinted many times. In spite of its popularity in India, this work does not actually treat mathematics in the Vedic periods. See K. S. Shukla, "*Vedic Mathematics*—The Deceptive Title of Swamiji's Book", in *Issues in Vedic Mathematics: Proceedings of the National Workshop on Vedic Mathematics, 25–28 March, 1988, at the University of Rajasthan, Jaipur*, edited by H. C. Khare, (Delhi: Motilal Banarssidass, 1991, reprinted 1994), 31–39; and R. C. Gupta, "Six Type of Vedic Mathematics", *Gaṇita Bhāratī* 16 (1994), 5–15.

Jaina Mathematics

1533. Datta, Bibhutibhusan. "The Jaina School of Mathematics". *Bulletin of the Calcutta Mathematical Society* 21 (1929), 115–145. Reprinted as

"The Mathematical Achievements of the Jaina" in Chattopadhyaya's *Studies*, item 1498, Vol. 2, 684–716.

Treats mensuration rules, combinatorics, law of indicies, place-value system, classification of numbers, and geometric configurations of points, found in the Jaina canonical and quasi-canonical literature.

1534. Gupta, Radha Charan. "Circumference of the Jambūdvīpa in Jaina Cosmography". *Indian Journal of History of Science* 10 (1975), 38–46.

Shows that in Jaina canonical and cosmographical works a root-approximation formula is used together with the formula, $C = \sqrt{10d^2}$, for calculating the circumference of the disk of the central continent called Jambūdvīpa. For the origin of $\sqrt{10}$ see Gupta's article, "Mādhavacandra's and Other Octagonal Derivations of the Jaina Value $\pi = \sqrt{10}$", *Indian Journal of History of Science* 21 (1986), 131–139.

1535. Jain, Lakṣmīcandra. *Exact Sciences from Jaina Sources.* Vol. 1 (*Basic Mathematics*), Vol. 2 (*Astronomy and Cosmology*). Jaipur: Rajasthan Prakrit Bharti Sansthan and New Delhi: Sitarambhartia Institute of Scientific Research, 1982/83.

The topics of Vol. 1 are divided in 6 chapters: introduction, the world history of mathematics, mathematics of the *Tiloyapaṇṇattī*, mathematics of the *Dhavalā*, mathematical topics common in Jaina works, comparison of Jaina mathematics with Egyptian, Greek, and Chinese mathematics.

1536. Sarasvati, T. A. "The Mathematics in the First Four Mahādhikāras of the Triloka-prajñapti". *Journal of the Ganganatha Jha Research Institute* 18 (1961/62), 27–51.

Provides Sanskrit renderings (called chāyā), with their English translations, of the original Prakrit verses containing mathematical rules found in the first four chapters of Jadivasaha's cosmographical work, *Tiloyapaṇṇattī*. The topics are geometry, mathematical series, and infinity.

1537. Singh, Avadesh Narayan. "History of Mathematics in India from Jain Sources". *Jaina Antiquary* 15 (2) (1949), 46–53; 16 (2) (1950), 54–69.

Survey and analysis of mathematical knowledge (indices, logarithms, fractions, and geometry) in the *Dhavalā* of Vīrasena. Includes a passage of the text, with English translation, in which Vīrasena calculates the volume of a frustum by decomposing it into an infinite number of component parts.

Arithmetic

See also the work of B. Datta and A. N. Singh (item 1499), Vol. 1, as well as the works on arithmetic and mensuration (pāṭī) listed here under Sources and Translations.

1538. Datta, Bibhutibhusan. "The Science of Calculation by the Board". *American Mathematical Monthly* 35 (1928), 520–529.

The author conjectures that the word *pāṭī* of *pāṭīgaṇita* is a corrupt form of the word *paṭṭa* meaning a slab or a tablet on which computation was performed.

1539. Gupta, Radha Charan. "Some Important Indian Mathematical Methods as Conceived in Sanskrit Language". *Indological Studies (University of Delhi)* 3 (1974), 49–62.

Rule of three, method of iteration, and method of average and their application in mathematics and astronomy. For iterative techniques used in trigonometry see K. Plofker's article, item 1568.

1540. Mazars, Guy. "Les fractions dans l'Inde ancienne de la civilisation de l'Indus à Mahāvīra (IX^{e} siècle)". In *Histoire de fractions, fractions d'histoire.* Edited by Paul Benoit, Karine Chemla, and Jim Ritter, eds. (Science Networks · Historical Studies 10.) Basel, Boston, Berlin: Birkhäuser Verlag, 1992, 209–218.

A survey of expressions of, and of operations on, fractions in India up to the 9th century A.D.

1541. Sarma, Sreeramula Rajeswara. "Some Medieval Arithmetical Tables". *Indian Journal of History of Science* 32 (1997), 191–198.

A historically important report on Prakrit tables for squares, square-roots, cubes, cube-roots, and multiplications by three, which are all cited in an anonymous Telugu commentary (date unknown) on Pāvulūri Mallana's Telugu translation (11th century) of Mahāvīra's *Gaṇitasārasaṃgraha*.

1542. Singh, Paramanand. "The So-called Fibonacci Numbers in Ancient and Medieval India". *Historia Mathematica* 12 (1985), 229–244.

Points out that Indian prosodists beginning with Virahāṅka (betweeen A.D. 600 and 800) recognized and explicitly stated that the numbers of possible verses in moric meters (regulated by the number of syllabic instants called mātrā or mora) make a sequence in which the sum of any two consecutive terms is equal to the next.

Mensuration (Geometry)

See also B. Datta and A. N. Singh's article, "Hindu Geometry" cited in item 1499 as well as the works on arithmetic and mensuration (pāṭī) listed here under Sources and Translations.

1543. Gupta, Radha Charan. "On the Volume of a Sphere in Ancient India". *Historia Scientiarum* 42 (1991), 33–44.

Detailed discussions about the formulas for the volume of a sphere given by Āryabhaṭa I, by the Jainas, and by Śrīdhara, with reference to the Sanskrit commentaries on them.

1544. Hayashi, Takao. "Calculations of the Surface of a Sphere in India". *The Science and Engineering Review of Doshisha University* 37 (1997), 194–238.

Provides verses and prose passages in Sanskrit related to the surface area of a sphere from the works of Āryabhaṭa I, Lalla, Mahāvīra, Āryabhaṭa II, Bhāskara II, Gaṇeśa, and Śaṅkara Vāriyar, with their English translations and mathematical commentaries on them.

1545. Hayashi, Takao, Takanori Kusuba, and Michio Yano. "Indian Values for π Derived from Āryabhaṭa's Value". *Historia Scientiarum* 37 (1989), 1–16.

Shows that the peculiar formula for the circumference of a circle cited by Vīrasena, which involves 355/113 for π, is an approximation to that of Āryabhaṭa I. With two lists (in chronological and numerical orders) of Indian values for π.

1546. Pottage, John. "The Mensuration of Quadrilaterals and the Generation of Pythagorean Triads: A Mathematical, Heuristical and Historical Study with Special Reference to Brahmagupta's Rules". *Archive for History of Exact Sciences* 12 (1974), 299–354.

Investigates possible derivations of Brahmagupta's rules for quadrilaterals by analyzing in detail the treatment of quadrilaterals and Pythagorean triads by Brahmagupta, Śrīdhara, Mahāvīra and Pṛthūdhakasvāmin (fl. 864, commentator of Brahmagupta's works).

1547. Sarasvatī, T. A. *Geometry in Ancient and Medieval India*. New Delhi: Motilal Banarsidass, 1979.

An informative book on Indian geometry, with a number of citations from original Sanskrit works with their translations, in 10 chapters: 1. Introduction (which discusses the characteristics of Indian geometry), 2. *Śulbasūtra* Geometry, 3. Early Jaina Geometry, 4. The Trapezium (a chronological description of its treatment in early Jaina literature and by major mathematicians from Āryabhaṭa I to Nārāyaṇa), 5. The Quadrilateral (mainly on cyclic quadrilaterals treated by Brahmagupta, Nārāyaṇa, Parameśvara, Śaṅkara Vāriyar and Jyeṣṭhadeva), 6. The Triangle (rational right triangles, etc.), 7. The Circle (approximations to π, area, Mādhava-Gregory series, inscribed polygons, etc.), 8. Volumes and Surfaces of Solids (pyramid, tetrahedron, frustum, and sphere), 9. Geometrical Algebra (geometric proofs of algebraic formulas, including those for series, and geometric solutions to algebraic problems, in *Śulbasūtras* and by mathematicians from Śrīdhara to Śaṅkara Vāriyar), 10. Shadow Problems and Other Problems (of Āryabhaṭa I, Brahmagupta, etc.). With a glossary of geometrical terms and a bibliography.

Combinatorics

See also B. Datta and A. N. Singh's article, "Use of Permutations and Combinations in India", cited in item 1499 and T. Kusuba's work in item 1482.

1548. Alsdorf, Ludwig. "Die Pratyayas: Ein Beitrag zur indischen Mathematik". *Zeitschrift für Indologie und Iranistik* 9 (1933), 97–157; reprinted in his *Kleine Schriften*, Wiesbaden: Franz Steiner Verlag GmbH, 1974, 600–660 ; translated into English by Sreeramula Rajeswara Sarma as "The Pratyayas: Indian Contribution to Combinatorics", *Indian Journal of History of Science* 26 (1991), 17–61.

Combinatorics, including the so-called Pascal's triangle, related to Sanskrit (and Prakrit) prosody from the works of Piṅgala (3rd century A.D. or later), Bharata (ca. 6th century or before), Kedāra (before 1100), Hemacandra (1089–1172), etc. See also Amulya Kumar Bag's article, "Binomial Theorem in Ancient India", *Indian Journal of History of Science* 1 (1966), 68–74, reprinted in *History of Science and Technology in India*, item 1504, Vol. 4, 191–200.

1549. Hayashi, Takao. "Indo ni okeru junretsu kumiawase rekkyo". (†Permutations, Combinations, and Enumerations in Ancient India†). *Kagakusi Kenkyu* II, 18 (1979), 158–171.

A survey of passages related to combinatorics in mathematical as well as non-mathematical works: the sources for the former are the works of Brahmagupta, Śrīdhara, Mahāvīra, Āryabhaṭa II, and Bhāskara II, and for the latter works on divination (by Varāhamihira), on horoscope (by Varāhamihira), on prosody (by Piṅgala, etc.), on music (by Śārṅgadeva), and on medicine (by Agniveśa). See also Hayashi's article, "Combinatorics in Indian Mathematics" in H. Selin's *Encyclopaedia*, item 1463, 229–230.

1550. Singh, Paramanand. "Nārāyaṇa's Treatment of Net of Numbers". *Gaṇita Bhāratī* 3 (1–2) (1981), 13–31.

English translations, with mathematical comments, of Nārāyaṇa's rules for the "net of digits" (combinatorics) given in the 13th chapter of his *Gaṇitakaumudī*.

Magic Square

See also B. Datta and A. N. Singh's article, "Magic Squares in India", cited in item 1499, T. Kusuba's work in item 1482, and C. Schuyler's article, item 1573.

1551. Hayashi, Takao. "Hōjinzan: A Japanese Translation of Chapter 14 of Nārāyaṇa's *Gaṇitakaumudī*. *Epistēmē* II, 3 (1986), i–xxxiv. "

The first modern translation, with mathematical commentary, of the chapter called bhadra-gaṇita (computation of magic squares) of

Nārāyaṇa's *Gaṇitakaumudī*. In the introduction the author analyzes the rules for magic squares prescribed in Ṭhakkura Pherū's *Gaṇitasāra*. See also Hayashi's article, "Magic Squares in Indian Mathematics" in H. Selin's *Encyclopaedia*, item 1463, 529–536.

1552. Hayashi, Takao. "Varāhamihira's Pandiagonal Magic Square of the Order Four". *Historia Mathematica* 14 (1987), 159–166.

Points out that Varāhamihira used an irregular, pandiagonal magic square of order 4, which is the earliest extant magic square in India, in order to prescribe preparation of perfume in his work on divination, *Bṛhatsaṃhitā*.

1553. Roşu, Arion. "Les carrés magiques indiens et l'histoire des idées en Asie". *Zeitschrift der Deutchen Morgenländischen Gesellschaft* 139 (1989), 120–158.

A detailed study of various Indian contexts where magic squares occur, such as medicine, archaeological findings, Hindu tantrism, Jaina hymns, and mathematics. Also discusses Arabic and Chinese magic squares, and points out similar medical usage of magic squares of order three in India and in the Islamic world. For the last topic see also Roşu's article, "Études āyurvédiques III. Les carrés magiques dans la médicine indienne", *Studies on Indian Medical History*, edited by G. Jan Meulenbeld and Dominik Wujastyk, (Groningen Oriental Series 2), Groningen: Egbert Forsten, 1987, 103–112.

Algebra

See also B. Datta and A. N. Singh's joint work (item 1499), Vol. 2.

1554. Colebrooke, Henry Thomas. *Algebra with Arithmetic and Mensuration from the Sanscrit of Brahmegupta and Bhāscara*. London: John Murray, 1817. Reprinted, Wiesbaden: Dr. Martin Sändig oHG, 1973.

Consists of English translations of Chapters 12 (arithmetic and mensuration) and 18 (algebra) of the *Brāhmasphuṭasiddhānta* of Brahmagupta and of the *Līlāvatī* (arithmetic and mensuration) and *Bījagaṇia* (algebra) of Bhāskara II. With an elaborate introduction called "Dissertation" (pp. i–lxxxiv). Pioneering work but still useful: the translations are precise and the footnotes include a number of citations, in English translation, from Sanskrit commentaries. The English translation of the *Līlāvatī* has been reprinted together with notes by Haran Chandra Banerji and with an edition of the Sanskrit text as *Colebrooke's Translation of the Līlāvatī*, Calcutta: The Book Company Ltd., 1892; 2nd edition, 1927 ;reprinted, New Delhi/Madras: Asian Educational Services, 1993. Part of the original introduction (pp. i–xxv) has been reprinted as "Introduction to Indian Algebra with Arithmetic and Mensuration" in Chattopadhyaya's *Studies*, item 1498, Vol. 2, 626–654.

1555. Datta, Bibhutibhusan. "Elder Āryabhaṭa's Rule for the Solution of Indeterminate Equation of the First Degree". *Bulletin of the Calcutta Mathematical Society* 24 (1932), 19–36.

Detailed discussion of Āryabhaṭa I's rule for the linear Diophantine equations (kuṭṭaka), with its English translation, based on Bhāskara I's commentary, relevant passages of which have been cited from a manuscript.

1556. Ganguli, Saradakanta. "India's Contribution to the Theory of Indeterminate Equations of the First Degree". *Journal of the Indian Mathematical Society/Notes and Questions* 19 (1931–1932), 110–120, 129–142, 153–168.

Describes the development of the kuṭṭaka theory in India from Āryabhaṭa I (5th century) to Bhāskara II (12th century).

1557. Hayashi, Takao, and Takanori Kusuba. "Twenty-One Algebraic Normal Forms of Citrabhānu". *Historia Mathematica* 25 (1998), 1–21.

Examines Citrabhānu's theory of algebraic normal forms up to the third degree as handed down to us by his pupil Śaṅkara in his commentary on the *Līlāvatī*, and surveys their history in India.

1558. Lal, Ramashankar, and Ramashis Prasad. "Integral Solutions of the Equation $Nx^2 + 1 = y^2$ in Ancient Indian Mathematics (Cakravāla or the Cyclic Method)". *Gaṇita Bhāratī* 15 (1993), 41–54.

Provides Sanskrit verses of Jayadeva, Bhāskara II and Nārāyaṇa with their translations, analyzes the rules contained in them, and illustrates them with examples.

1559. Selenius, Clas-Olof. "Rationale of the Chaklavāla Process of Jayadeva and Bhāskara II". *Historia Mathematica* 2 (1975), 167–184.

A study of the mathematical meaning and validity of the cakravāla (cyclic) method for the solution of $Nx^2 + 1 = y^2$ from the viewpoint of the theory of the ideal continued fractions. See also Paramanand Singh, "Varga-Prakṛti: the Cakravāla Method of Its Solution and the Regular Continued Fractions", *Indian Journal of History of Science* 19 (1984), 1–17.

1560. Shukla, Kripa Shankar. "Ācārya Jayadeva, the Mathematician". *Gaṇita* 5 (1954), 1–20.

A historically important report on Udayadivākara's (A.D. 1073) quotations from Jayadeva's work (whose title and date are unknown), which deals with the vargaprakṛti, a theory of general Pellian equations, including the cakravāla (cyclic) method.

Trigonometry

See also B. Datta and A. N. Singh's articles, "Hindu Trigonometry" and "Use of Calculus . . .", cited in item 1499.

1561. Gold, David, and David Pingree. "A Hitherto Unknown Sanskrit Work concerning Mādhava's Derivation of the Power Series for Sine and Cosine". *Historia Scientiarum* 42 (1991), 49–65.

An edition and translation, with a mathematical commentary, of an anonymous commentary on three verses that prescribe power series of Mādhava of Saṅgamagrāma (fl. 1380/1420). Two out of the three verses have been attributed to Mādhava by Nīlakaṇṭha in his commentary on the *Āryabhaṭīya*. See R. C. Gupta, "Mādhava's Power Series Computation of the Sine", *Ganita* 27 (1976), 19–24. K. V. Sarma (item 1462, 149) hypothetically regards the verses as constituting Mādhava's lost work called *Mahājyānayanaprakāra* (Method for the Computation of the Major Sines).

1562. Gupta, Radha Charan. "Addition and Subtraction Theorems for the Sine and the Cosine in Medieval India". *Indian Journal of History of Science* 9 (1974), 164–177.

Describes the rules given by Bhāskara II, Mādhava, and Munīśvara, and their proofs or derivations given, or cited, by Munīśvara, Nīlakaṇṭha, and Kamalākara.

1563. Gupta, Radha Charan. "Bhāskara I's Approximation to Sine". *Indian Journal of History of Science* 2 (1967), 121–136.

An analysis, with investigation into the origin, of a remarkable approximation to sine by a rational function, which has been known to Indian mathematicians since the 7th century A.D.

1564. Gupta, Radha Charan. "Second Order Interpolation in Indian Mathematics up to the Fifteenth Century". *Indian Journal of History of Science* 4 (1969), 86–98.

Analyzes the rules for the second order interpolation of tabular values of triginometric functions, such as sine and cosine, given by Brahmagupta, Govindasvāmin, Bhāskara II, Mādhava, and Parameśvara.

1565. Hayashi, Takao. "Āryabhaṭa's Rule and Table for Sine-Differences". *Historia Mathematica* 24 (1997), 396–406.

Reconstructs the derivation process of Āryabhaṭa I's table of sine-differences given in Chapter 1 of his *Āryabhaṭīya* from his own rule on sine-differences given in Chapter 2 of the same work.

1566. Hayashi, Takao, Takanori Kusuba, and Michio Yano. *Indo sūgaku kenkyū: Sūretsu enshūritsu sankakuhō.* (†Studies in Indian Mathematics: Series, Pi and Trigonometry†.) Tokyo: Kōseisha kōseikaku, 1997.

Divided into 5 chapters. Chapter 1 contains a Japanese translation, with mathematical commentary, of Śaṅkara Vāriyar's commentary on verse 199 of the *Līlāvatī*, which outlines the rationales of Mādhava's two methods for calculating the circumference of a circle. Chapter 2 contains a Japanese translation, with mathematical commentary, of Nīlakaṇṭha's commentary on *Āryabhaṭīya* 2.7 (on a circle and a sphere), 2.10–12 (on π and trigonometry), and 2.19–22 (on series). Chapters 3 to 5 are in order devoted to studies of the histories of series, of π, and of trigonometry in India. The 7 appendices include a chronological table of Sanskrit mathematical works, bibliography, parallel passages of Śaṅkara's works, and glossaries of mathematical terms. See also the same authors' article, "The Correction of the Mādhava Series for the Circumference of a Circle", *Centaurus* 33 (1990), 149–174.

1567. Mukhopadhyay, A. and M. R. Adhikari. "Polygonal Approximation to Circle and Mādhavācārya". *Indian Journal of History of Science* 30 (1995), 35–45.

Describes one of the two methods of Mādhava for computing the circumference of a circle— Mādhava's verses have been cited by Śaṅkara Vāriyar in his commentary on the *Līlāvatī*.

1568. Plofker, Kim. "An Example of the Secant Method of Iterative Approximation in a Fifteenth Century Sanskrit Text". *Historia Mathematica* 23 (1996), 246–256.

Discusses the iterative techniques prescribed by Mādhava's disciple, Parameśvara, for calculating the Sine of a given arc.

1569. Rajagopal, C. T., and M. S. Raṅgāchāri. "On an Untapped Source of Medieval Keralese Mathematics". *Archive for History of Exact Sciences* 18 (1978), 89–102.

Provides Sanskrit verses containing series expansions of trigonometric functions such as sine, arctangent, etc. with their English translations. The source is Śaṅkara Vāriyar's commentary, *Yuktidīpikā*, on Nīlakaṇṭha's *Tantrasaṃgraha*. See also the same authors' article, "On Medieval Kerala Mathematics", *Archive for History of Exact Sciences* 35 (1986), 91–99.

1570. Sarasvatī, T. A. "The Development of Mathematical Series in India after Bhāskara II". *Bulletin of the National Institute of Sciences of India* 21 (1963), 320–343.

A very good account of the subject. The main topics are the infinite series for π and the sine and cosine power series developed in India up to the 16th century.

Weights and Measures

1571. Srinivasan, Saradha. *Mensuration in Ancient India*. New Delhi: Ajanta Publication, 1979.

A good study of weights and measures found in the literatures of different fields as well as in archaeological excavations. After an introduction the author treats in order linear measures, area measures, volume measures, weights, and time. See also Srinivasan's article, "Evolution of Weights and Measures in Ancient India", *Gaṇita Bhāratī* 4 (1982), 17–25.

Transmission and Education

1572. Bag, Amulya Kumar. "Kuṭṭaka and Qiuyishu". *Indian Journal of History of Science* 19 (1984), 397–405. Reprinted in the book edited by Kuppuram and Kumudamani, item 1504, Vol. 2, 399–411.

A comparative study of the Indian and the Chinese solutions to indeterminate equations of the first degree.

1573. Cammann, Schuyler. "Islamic and Indian Magic Squares". *History of Religion* 8 (1968–1969), 181–209, 271–299.

One of a series in the author's comparative study of magic squares in China, India, and the Islamic world, with special attention to their transmission and religious background.

1574. Chakrabarti, Gurugovinda. "Typical Problems of Hindu Mathematics". *Annals of the Bhandarkar Oriental Research Institute* 14 (1932–1933), 87–102.

A comparative study of the so-called "typical" or "standard" or "stock" problems widely spread among ancient and medieval nations. See also H. Hermelink, "Arabic Recreational Mathematics as a Mirror of Age-Old Relations between Eastern and Western Civilizations" in *Proceedings of the First International Symposium for the History of Arabic Sciences*, part 2 (English section), Aleppo, 1976, 44–52.

1575. Chattopadhyaya, Debiprasad. *History of Science and Technology in Ancient India: The Beginnings*. Calcutta: Firma KLM, 1986.

In Chapters 5–7, entitled respectively "Mathematics in the Making", "Technicians and the Vedic Priests", and "Science in First Urbanisation", the author argues for a possible connection between Śulba mathematics and the Indus Civilization. Appendix I provides a summary, in modern expression, of geometric propositions contained in the *Baudhāyana Śulbasūtra*.

1576. Gupta, Radha Charan. "Sino-Indian Interaction and I-Hsing". *Gaṇita Bhāratī* 11 (1989), 38–49.

A survey of various aspects of the Sino-Indian interaction (mainly from India to China). The topics treated are Buddhist works that contain mathematical or astronomical passages, several works on calendar, and mathematical problems known both in China and in India such as "the broken bamboo problem", "the inclined reed problem", and "the hundred fowls problem".

1577. Gupta, Radha Charan. "Spread and Triumph of Indian Numerals". *Indian Journal of History of Science* 18 (1983), 23–38.

An extensive survey, based mainly on secondary sources, of use or mention of the Indian numerals with the decimal place-value system, made outside India from the 5th to the 17th centuries A.D. The entries are arranged chronologically.

1578. Kapur, J. N. "A Brief History of Mathematics Education in India". *Gaṇita Bhāratī* 10 (1988), 31–39.

Includes ancient and medieval periods, but devotes most pages to the periods after the consolidation of the British rule in India, that is, from the late 18th century.

1579. Maiti, N. L. "Notes on Broken Bamboo Problem". *Gaṇita Bhāratī* 16 (1994), 25–36.

Analyzes Bhāskara I's treatment, in his commentary on the *Āryabhaṭīya*, of "the broken bamboo problem" in detail, and argues for the possibility that the problem originated in India.

1580. Majumdar, Pradip Kumar. "Studies of Mathematics in Three Hundred Years Old Calcutta". *Gaṇita Bhāratī* 15 (1993), 55–66.

A study of the introduction process of European mathematics into India in the 19th and the 20th centuries.

1581. Ōhashi, Yukio. "Astronomy in Tibet". In *Encyclopaedia* etc. (item 1463) 136–139.

Tibetan astronomy has been influenced by the fundamental text of the Kālacakra-yāna Buddhism, *Kālacakratantra*, which the author considers as written in India in the 11th century A.D. He also points out that the astronomical constants used by Bu-ston (A.D. 1290–1364) are close to those of the Ārdharātrika school of Indian astronomy (for which see under item 1506).

1582. Pingree, David. "The Indian and Pseudo-Indian Passages in Greek and Latin Astronomical and Astrological Texts". *Viator: Medieval and Renaissance Studies* Berkeley: University of California Press 7 (1976), 141–195.

Traces the transmission of the subjects from Sanskrit through Arabic to Greek and Latin texts in 19 entries including the *Zīj al-Sindhind* (influenced by the Brāhma school of Indian astronomy) and Abū Maʿshar, who transmitted Indian astrology to the Arabs.

1583. Pingree, David. "Power Series in Medieval Indian Trigonometry". In *Proceedings of the South Asia Seminar*. Vol. II. Pennsylvania:

University of Pennsylvania (Department of South Asia Regional Studies), 1981/1982, 25–30.

Discusses the limited transmission of the knowledge of the power series for trigonometric functions discovered by Mādhava of Saṅgamagrāma, Kerala. See also Chapter 9 of Pingree's work, *Jyotiḥśāstra*, item 1460.

1584. Rocher, Ludo J. "Euclid's Stoicheia and Jagannātha's Rekhāgaṇita". *Journal of the Oriental Institute, Baroda* 3 (1953/54), 236–256.

A comparative study between the definitions of mathematical terms in Jagannātha's Sanskrit translation of an Arabic version of Euclid's *Elements* and those in its Greek original.

1585. Saidan, A. S. *The Arithmetic of al-Uqlīdisī.* Dordrecht and Boston: D. Reidel Publishing Company, 1978.

English translation of the earliest extant Arabic work of Hindu arithmetic, *Kitāb al-Fuṣūl fī al-Ḥisāb al-Hindī* of al-Uqlīdisī (10th century), with an introduction and commentary.

1586. van der Waerden, B. L. *Geometry and Algebra in Ancient Civilizations.* Berlin: Springer Verlag, 1983.

Proposes a number of conjectures about transmission of mathematical ideas. The three main cases of transmission conjectured are: from Central Asia, where a pre-Babylonian mathematics existed according to the author, to Great Britain, the Near East, India, and China (the Pythagorean Theorem and related problems), from Alexandria to India (solutions to the Diophantine equations), and from Greece to China and India (measurement of the circle and trigonometry). For an objection to van der Waerden's conjectures see A. K. Bag, "Ritual Geometry in India and Its Parallelism in Other Cultural Areas", *Indian Journal of History of Science* 25 (1990), 4–19.

1587. Yabuuti, Kiyosi. "Researches on the *Chiu-chih li* — Indian Astronomy under the T'ang Dynasty". *Acta Asiatica* 36 (1979), 7–48.

Provides an English translation, with mathematical commentary, of a Chinese work on the Indian calendar, *Chiu-chih li*, written by Chut'an Hsita (Gotama Siddha in Sanskrit) in A.D. 718. The calendar is based on that of the Ārdharātrika school (for which see under item 1506). See also M. Yano, "The *Chiuchih-li* and the Ārdharātrika-pakṣa: On the True Daily Motion of the Moon", *Journal of Indian and Buddhist Studies (Indogaku Bukkyōgaku Kenkyū)* 27 (1979) 2, 953–956. Gotama Siddha in the introductory part lists the Indian decimal numerals including a dot for "a vacant place" and explains them (the numerical figures in the text have been lost).

1588. Yano, Michio. "The Hsiu-yao Ching and Its Sanskrit Sources". *History of Oriental Astronomy: Proceedings of an International Astronomical Union Colloquium No. 91, New Delhi, 13–16 November 1985.* Edited by G. Swarup, A. K. Bag, and K. S. Shukla. Cambridge: Cambridge University Press, 1987, 125–134.

Traces the origin and development of a Chinese text on Indian astrology, *Hsiu-yao Ching*, by a Buddhist monk of an Indian origin, Amoghavajra (A.D. 706–774).

HEBREW MATHEMATICS

Parallel to the main streams of medieval learning which flowed in Arabic and Latin was a smaller but vigorous one in Hebrew. Because Jews were spread through both Islam and Christendom, intellectual contact between the two was sometimes mediated through Hebrew, and there are Arabic works that survive only in Hebrew translations. Moreover, a significant number of these Hebrew treatises were translated into Latin and were consulted by European scholars for several centuries. It should also be noted that many original contributions were made by these authors (especially Levi ben Gerson), not all of which have been adequately explored in the modern secondary literature. Because so much of the material remains in manuscript form, the bibliographies (see, for example, items 1636, 1637, and 1638) contain much information not available elsewhere.

The bibliography that follows covers the Hebrew tradition in mathematics from antiquity until early modern times when Jewish scientists began to write in European languages. Because of its close identification with mathematics some literature in astronomy is also cited here.

In its earliest phases, Hebrew mathematics derived from Oriental and Babylonian origins. In the Middle Ages it was nourished from Arabic translations of Greek works and developed close links with developments in the Muslim world. Hebrew scientific works were written primarily in Spain and southern France, but a number of authors lived in other parts of the Mediterranean basin, e.g., Greece, Turkey, Italy, Egypt, and some in other places, e.g., Yemen. The period most strongly represented is the one extending from the 12th to the 15th centuries. Interest was centered on algebra, geometry, number theory, trigonometry, and mathematical astronomy (including mathematical tables for calculating planetary positions).

General Studies

1589. Abner de Burgos. *Alfonso .Meyaššer ʿAqov. Straightening the Curves.* Original Hebrew text edited and translated into Russian by Gitta Gluskina. Commentary by Gitta Gluskina, S. I. Luria, and B. A. Rosenfeld. Izdatelstvo Nauka, 1983.

Alfonso is the Christian name of Abner de Burgos (1270-1350), an educated, converted Jew, who dedicated this work to aspects of philosophy and mathematics concerning the quadrature of the circle. There are references to Greek, Arab, and Latin authors.

1590. Chemla, Karine, and Serge Pahaut. "Remarques sur les ouvrages mathématiques de Gersonide". In G. Freudenthal. *Studies on Gersonides.* Leiden: Brill, 1992, 149-191.

Two important texts by Levi ben Gerson appear here with commentary: his great work on arithmetic, *Sefer Maʿaseh Ḥoshev*, (†The Book on the Work of the Reckoner†), written in Hebrew in Provence in the XIVth century; and the *De numeris harmonicis*, which has come down to us in its Latin version.

1591. Clagett, Marshall. *Archimedes in the Middle Ages. Part III, The Fate of the Medieval Archimedes: 1300 to 1565.* Philadelphia, 1978.

Contains references to the propagation in Europe of the geometry of Abraham Bar Ḥiyya, from the Latin version attributed to Platon de Tivoli *Liber embadorum*, as well as indications on *Quadrans novus*, adapted into Latin from a work drafted in Hebrew by Jacob ben Makhir de Montpellier, from the XIIIth century, *The Quadrant of Israel, Rovaʿ Yisra'el.*

1592. Curtze, Maximilian. "Der *Liber embadorum* des Savasorda in der Übersetzung des Plato von Tivoli". In *Urkunden zur Geschichte der Mathematik im Mittelalter und der Renaissance.* Leipzig, 1902, 1-183.

Abraham bar Ḥiyya, better known in Latin by the name of Savasorda, assisted the Latin translator Platon de Tivoli in translating Arabic texts. The text offered here (accompanied by a translation in German) is a translation from Hebrew into Latin. It is difficult to know if Savasorda contributed to the perfection of the Latin text, especially since the Latin deviates at times from the Hebrew, such as we know it.

1593. Feldman, W. M. *Rabbinical Mathematics and Astronomy.* London, 1931. Reprinted New York: Hermon Press, 1965.

Although marred by omissions and errors, this book can serve as an introduction to the field.

1594. Freudenthal, Gad. "Maimonides' *Guide for the Perplexed* and the Transmission of the Mathematical Tract 'On Two Asymptotic Lines' in the Arabic, Latin and Hebrew Medieval Traditions". *Vivarium* XXVI (1988), 113-140.

The history of the propagation of a small Arabic treatise, which adapts a result from the *Conic Sections* by Apollonius (Prop. II, 14) concerning the asymptotic property of the hyperbola.

1595. Freudenthal, Gad. "Les sciences dans les communautés juives médiévales de Provence: leur appropriation, leur rôle". *Revue d'études juives* CLII (1993), 29-136.

This article outlines the reception of science, particularly mathematics, in the Jewish, Hebrew-speaking communities of medieval France from the XIIth to the XIVth centuries. It is reprinted in condensed form in Gad Freudenthal, "Science in the Medieval Jewish Culture of Southern France", *History of Science* XXXIII (1995), 23-58.

1596. Gandz, Solomon. *Studies in Hebrew Astronomy and Mathematics.* Selected, with an Introduction, by S. Sternberg. New York: Ktav, 1970, 544 pp.

A reprint of 15 essays that appeared between 1927 and 1951. Gandz's approach to the Hebrew sources was to see them in the context of Babylonian, Greek, and Arabic traditions. Perhaps the most important of these essays is his edition and commentary of the *Mishnat ha-Middot*, an early treatise on geometry in Hebrew that Gandz dated ca. 150 A.D., but that Sarfatti (item 1634 below, pp. 58–60) argues persuasively belongs to the early Islamic period. There are also essays on the Jewish calendar, the astrolabe, Hebrew numerals, and Saadya Gaon (10th century) as a mathematician. Review: Goldstein, B. R., *Speculum* 47 (1972), 124–125.

1597. Gandz, Solomon. "The Mishnat ha-Middot, the First Hebrew Geometry about 150 C.E., and the *Geometry of al-Khowarizmi*, the First Arabic Geometry (ca. 820) Representing the Arabic Version of the Mishnat ha-Middot. Texts with English Translation, Introduction and Notes". *Quellen und Studien zur Geschichte der Mathematik und Physik.* A2 Berlin: Springer, 1932.

Gandz relates the *Mishnat ha-Middot* to Heron and his school, placing it in the Oriental tradition of devising mathematical tools for practical applications rather than exploring theory (pure science) for its own sake.

This must be read in conjunction with the articles by Gad B. Sarfatti, "The Mathematical Terminology of the *Mishnat ha-Middot*" (Hebrew), *Leshonenu* 23 (5719), 156–171, and 24 (5720), 88–94, which also contain an improved text and "Some Remarks about the Prague manuscript of *Mishnat ha-Middot*", *Hebrew Union College Annual* XLV (1974), 197-204. This Prague manuscript, published by Alexander Scheiber, *Hebrew Union College Annual*, 191-196 has brought to light a new text fragment, thus completing what was already known. Sarfatti refutes Gandz's early dating and ascribes the *Mishnat ha-Middot* to the 9th century or even later. This work by Gandz is reprinted in item 1596.

1598. Gandz, Solomon. “The Invention of the Decimal Fractions and the Application of the Exponential Calculus by Immanuel Bonfils of Tarascon (c. 1350)”. *Isis* 25 (1936), 16–45.

A classic study of work relating to the introduction of decimal fractions by Immanuel Bonfils (14th century, southern France). Gandz’s claims for Bonfils have been modified by subsequent work on Arabic mathematics, and Bonfils is no longer considered to have played the crucial role in this development (see P. Luckey, *Die Rechenkunst bei Ǧamšīd b. Masʿūd al-Kāšī*, item 1364, especially p. 120 ff, and R. Rashed, “L’extraction de la racine $n^{\text{ième}}$ et l’invention des fractions décimales”, item 1391). In addition to the manuscripts cited by Gandz, see MS Paris, Bibliothèque Nationale, Hebrew, 903, fol. 138a.

1599. Goldstein, Bernard R. “The Astronomical Tables of Levi ben Gerson”. *Transactions of the Connecticut Academy of Arts and Sciences* 45 (1974), 1–285.

An edition of the astronomical tables of Levi ben Gerson (14th century, southern France) with an introduction to his other astronomical achievements, including his wide-ranging discussion of possible astronomical models and a description of his profound modifications of Ptolemy’s lunar model. Unlike most medieval table-makers, Levi did not simply copy tables from the works of his predecessors; rather he recomputed them anew often changing the underlying parameters based on his own observations. The mathematical structure of the tables is displayed in the editor’s notes and, as a result of this study, it is clear that Levi was truly outstanding among those who wrote in Hebrew in the Middle Ages. Indeed his work compares favorably with contemporary achievements by those who wrote in Latin and Arabic. Review: Moesgaard, K. P., *Centaurus* 21 (1977), 197–199.

1600. Goldstein, Bernard R. *Ibn al-Muthannā’s Commentary on the Astronomical Tables of al-Khwārizmī*. New Haven: Yale University Press, 1967, 406 pp.

An edition with translation and commentary of the two surviving Hebrew versions of this text. The earliest phase of Islamic astronomy was deeply influenced by Indian sources, but it was largely displaced with the introduction of Greek methods in the 9th century. In reconstructing the early phase we are forced to depend on fragments preserved in later texts as well as commentaries on treatises that no longer survive. In this case, the Arabic text of Ibn al-Muthannā (10th century) is only preserved in Hebrew, but its information on the original form of al-Khwārizmī’s tables is most valuable. The commentator attempted unsuccessfully to explain Hindu procedures in terms of the Greek models. In one of the Hebrew versions, Ibn Ezra (12th century, Spain) added an introduction which gives his understanding of the transmission of Indian science to the Islamic world. An edition of the Latin version of this text has also appeared: E. Millás Vendrell, *El Commentario de Ibn al-Mutannā a las Tablas Astronomicas de al-Jwārizmī ... en la version de Hugo Sanctallensis* (Madrid, Barcelona: Consejo Superior de Investigaciones Cientificas, 1963).Review: Pingree, D., *Speculum* 43 (1968), 722 –724.

1601. Goldstein, Bernard R. "The Role of Science in the Jewish Community in Fourteenth Century France". *Annals of the New York Academy of Sciences* 314 (1978), 39–49.

A survey of intellectual achievements of a highly productive Jewish community and the relationship with their Spanish predecessors. Both translations and original works are discussed, including those of Samuel ben Judah of Marseille, Kalonymos ben Kalonymos of Arles, Levi ben Gerson of Orange, Immanuel ben Jacob Bonfils of Tarascon, and Shelomo ben David of Rodez.

1602. Goldstein, Bernard R. "The Survival of Arabic Astronomy in Hebrew". *Journal for the History of Arabic Science* 3 (1979), 31–39.

Argues that Hebrew manuscripts are an important source for Arabic science in three categories: (1) Arabic texts written in Hebrew characters, (2) translations (where the original does not always survive), and (3) original Hebrew treatises based on Arabic models. A number of texts are identified here for the first time, including a 19th-century copy of Ibn al-Shātir's *al-zīj al-jadīd*, originally composed in the 14th century.

1603. Goldstein, Bernard R., ed. *The Astronomy of Levi ben Gerson (1288-1344). A Critical Edition of Chapters 1-20 with Translation and Commentary*. New York, Berlin, Heidelberg, Tokyo: Springer Verlag, 1985.

The first known edition of part of the grand work on astronomy by Levi ben Gerson.

1604. Guttmann, Michael, ed. *Chibbur ha-Meschiha we ha-Tischboret. Lehrbuch der Geometrie des Abraham des Chija*. Berlin, 1912 and 1913.

An edition, with introduction and annotations, of the Hebrew treatise on geometry of Abraham Bar Ḥiyya (XIth-XIIth centuries). The Hebrew text has been translated into Catalan by Millás-Vallicrosa (item 1626).

1605. Juschkewitsch, Adolf P. *Geschichte der Mathematik im Mittelalter*. Leipzig: B. G. Teubner, 1964.

Contains some material on Jewish mathematicians, relating their work to overall developments. See also items 1231, 1666.

1606. Knorr, Wilbur, R. "The Medieval Tradition of a Greek Mathematical Lemma". *Zeitschrift für Geschichte der Arabisch-Islamischen Wissenschaften* 3 (1986), 230-61.

The handing down of the *Spherics* by Theodosius of the Middle Ages is analyzed in its different versions: Arabic, Latin, and Hebrew.

1607. Knorr, Wilbur, R. *Textual Studies in Ancient and Medieval Geometry.* Boston, Basel, Berlin: Birkhäuser, 1989.

The third part, ("The Textual Tradition of Archimedes' *Dimension of the Circle*"), contains an analysis of a Hebrew version of the text by Archimedes (reproduced in facsimile) and also passages from the Hebrew version of *On the Sphere and Cylinder* of Archimedes.

1608. Langermann Tzvi,Y. "The Mathematical Writings of Maimonides". *The Jewish Quarterly Review* LXXV (1984), 57-65.

The author presents an Arab text, entitled *Notes on Some of the Propositions of the Book of Conics.* Maimonides, identified here by his Arab name, puts forth complementary explanations for various passages from the works of Apollonius. The article also analyses the evidence of the Arabic bibliography, *al-Qifṭī*, concerning the mathematical activities of Maimonides in Egypt.

1609. Langermann Tzvi,Y., and J. P. Hogendijk. "A Hitherto Unknown Hellenistic Treatise on the Regular Polyhedra". *Historia Mathematica* 11 (1984), 325-326.

Langermann presents the Hebrew version of an Arab text, broadly expounding upon Book XIV of the *Elements* of Euclid, arranged by Hypsicles. For his part, Hogendijk presents the Arab text (published after this date on his own) of commentary by d'al-Maghribī, devoted to these same questions.

1610. Langermann Tzvi,Y. "Medieval Hebrew Texts on the Quadrature of the Lune". *Historia Mathematica* 23 (1996), 31-53.

1611. Lévy, Tony. "L'étude des sections coniques dans la tradition médiévale hébraïque. Ses relations avec les traditions arabe et latine". *Revue d'Histoire des Sciences* XLII (1989), 193-239.

Presentation, mathematical analysis, and examination of Arabic and Latin sources of several Hebrew texts concerned with the asymptotic property of the hyperbola.

1612. Lévy, Tony. "Le chapitre I, 73 du *Guide des égarés* et la tradition mathématique hébraïque au Moyen Age. Un commentaire inédit de Salomon b. Isaac (édition critique et traduction)". *Revue des études juives* CXLVIII (1989), 307-336.

One of the texts from the previous item, 1611.

1613. Lévy, Tony. "Mathématiques et penseurs juifs médiévaux: l'exemple de Maïmonide (1138-1204) et de Joseph ibn 'Aknin (ca. 1150- 1220)". In Doris Bensimon, ed. *Judaïsme, sciences et techniques.* (Collection "Colloques Langues'O".) Paris, 1989. 45-61.

The place of mathematics in education and its status as science, by two Jewish, Arab-speaking thinkers.

1614. Lévy, Tony. "Gersonide, le Pseudo-Ṭūsī et le postulat des parallèles". *Arabic Sciences and Philosophy* 2 (1992), 39-82.

Analysis of three attempts to provide a proof of postulate 5 of Euclid's *Elements*: that of Moses ha-Levi of Sevilla (XIIIth century), of Alfonso of Valladolid (XIVth century) and of Levi ben Gerson (XIVth century).

1615. Lévy, Tony. "Gersonide commentateur d'Euclide. Traduction annotée de ses gloses sur les *Eléments*". In G. Freudenthal, ed. *Studies on Gersonides.* Leiden: Brill, 1992, 83-147.

This analysis of sources of the medieval commentator (Gersonides) provides a large number of references from versions of Euclid's *Elements* in Arabic, Labin, and Hebrew, as well as the principal medieval commentaries on Euclid's text.

1616. Lévy, Tony. "Note sur le traitement des fractions dans les premiers écrits mathématiques rédigés en hébreu (XIe-XIIe s)". In P. Benoît, K. Chemla, and J. Ritter, eds. *Histoire des fractions et fractions d'histoire.* Basel, Boston, Berlin: Birkhäuser Verlag, 1992, 277-289.

The writing of fractions in the Bible, in rabbinical texts, in the works of Abraham bar Ḥiyya and Abraham ibn Ezra.

1617. Lévy, Tony. "L'histoire des nombres amiables: le témoignage des textes hébreux médiévaux". *Arabic sciences and philosophy* 6 (1996), 63-87.

An analysis of unpublished Hebrew texts which provides an explanation of the propagation, in medieval Europe, of the theorems founded in the arabic-islamic East by Thābit ibn Qurra in the IXth century. Are the results on amicable numbers given by Descartes and Fermat in the seventeenth century related to this propagation?

1618. Lévy, Tony. "La littérature mathématique hébraïque en Europe (XIe - XVIe siècles)". In Goldstein C., J. Gray, and J. Ritter, eds. *L'Europe mathématique - Mythes, histoires, identités. Mathematical Europe - Myth, History, Identity.* Paris, 1996, 83-99.

A general view. French version, revised and enlarged, of the following English text.

1619. Lévy, Tony. "Hebrew Mathematics in the Middle Ages: An Assessment". In F. Ragep, and S. Ragep, eds., *Tradition, Transmission, Transformation*. Leiden, New York, Cologone: Brill, 1996, 71-88.

1620. Lévy, Tony. "Fragment d'Ibn al-Samḥ sur le cylindre et ses sections planes, conservé dans une version hébraïque". Translation, notes, and glossary. In R. Rashed, ed. *Les mathématiques infinitésimales du IXe au XIe siècle*. Vol. 1. (Fondateurs et commentateurs.) London: Al-Furqān. Islamic Heritage Foundation, 1996, 927-973, 1080-1083.

The lost Arabic text of this Andalusian geometer (Xth-XIth centuries), represents, without any doubt, the best research put forth in the area of curves and surfaces associated with the sphere, cylinder and cone. The Hebrew text fragment analyzes the ellipse, defined by its bifocal property, as a plane section of a right or oblique cylinder, and demonstrates the formula for the area of an ellipse and that of an elliptic segment.

1621. Lévy, Tony. "Les *Eléments* d'Euclide en hébreu (XIIIe - XVIe siècles)". In M. Aouad, A. Elamrani-Jamal, and A. Hasnaoui eds., *Perspectives arabes et médiévales sur la tradition scientifique et philosophique grecque*. Paris, Louvain: Peeters, 1997, 79-94.

This article presents the complete corpus of different Hebrew versions of the *Elements* (31 manuscripts identified). It follows that we may count not two, but four separate (though not independent) translations from Arabic sources, and two translations clearly from Latin sources.

1622. Lévy, Tony. "Une version hébraïque inédite des *Eléments* d'Euclide." In *Les voies de la science grecque*. Edited by D. Jacquart. Geneva: Droz, 1997, 181-239.

A detailed analysis of an unpublished Hebrew version, which reproduces numerous readings related to the Arabic version (or versions) attributed to the first Arab translator of the *Elements*, al-Ḥajjāj (VIIIth-IXth centuries).

1623. Lévy, Tony. "The Establishment of the Mathematical Bookshelf of the Medieval Hebrew Scholar (XIIIth-XIVth century): Translations and Translators". *Science in Context* 10 (1997), 431-451.

The state of recent research concerning the large project of translating mathematical texts from Arabic to Hebrew.

1624. Millás Vallicrosa, J. M. *La obra Sefer Ḥeshbon mahlekot hakokabim de R. Abraham Bar Ḥiyya ha-Bargeloni*. Barcelona: Instituto Arias Montano, 1959, 270 pp.

An edition with translation and notes of a 12th-century Hebrew introduction to a set of astronomical tables. This text played a significant role in the transmission of Arabic astronomy to the Jewish communities of northern Spain and southern France where Arabic was not widely known. Bar Ḥiyya depends very heavily on the work of al-Battānī (d. 929). A glossary of technical terms is included. See also items 1343, 1642, and 1643.

1625. Millás Vallicrosa, J. M. *La obra enciclopedica Yesode ha-Tebuna U-Migdal ha-Emuna de R. Abraham Bar Ḥiyya ha-Bargeloni.* Madrid, Barcelona, 1952.

A Hebrew text, edited and translated into Spanish of a mathematical fragment from an encyclopedia on science, written in Hebrew in the XIIth century. Besides the historical interest provided by the text, the reader will note its importance for the study of mathematical lexicography.

1626. Millás Vallicrosa, J. M. *Abraam bar Hiia, Libre de geometria.* Barcelona, 1931.

Translation into Catalan of the Hebrew text edited by M. Guttmann (item 1604).

1627. Rabinovitch, Nachum L. "Early Antecedents of Error Theory". *Archive for History of Exact Sciences* 13 (1974), 348–358.

Citations from the Talmud and medieval rabbinic and astronomical authors, especially Levi ben Gerson, show that ancient and medieval scientific observers as well as artisans and lawyers were concerned with experimental and observational error, and devised rudimentary statistical rules to take it into account. These include replication of measurements and averaging data.

1628. Rabinovitch, Nachum L. *Probability and Statistical Inference in Ancient and Medieval Jewish Literature.* Toronto: University of Toronto Press, 1973, 205 pp.

Discusses rabbinic logic, random mechanisms in the Bible, statistical inference in the Talmud, and the treatment of combinations and permutations by medieval Hebrew writers. See also item 3669. Review: Zabell, S. *Journal of the American Statistical Association* 71 (1976), 996–998.

1629. Renan, E. "Les rabbins français du commencement du XIV^e^ siècle". *Histoire Littéraire de la France* 27 (1877), 431–764.

This is a bio-bibliographical study, arranged by the author, of Jewish scholars in France, based on both printed and manuscript sources with detailed references to the primary and secondary literature. Since a significant proportion of the authors treated wrote on mathematical subjects, this work is extremely valuable.

1630. Renan, E. "Les écrivains juifs français du XIV^e^ siècle". *Histoire Littéraire de la France* 31 (1893), 351–789.

A continuation of item 1629.

1631. Romano, D. “La transmission des sciences arabes par les juifs en Languedoc”. In *Juifs et judaisme de Languedoc.* Edited by M.-H. Vicaire and B. Blumenkranz. Toulouse: E. Privat, 1977, 363–386.

A discussion of the role of the Jews, particularly of the Kimḥi and Ibn Tibbon families, in the transmission of Arabic science to southern France in the 12th to 14th centuries. The most prolific translator, Moses ibn Tibbon (13th century), receives extensive treatment.

1632. Sacerdote, Gustavo. “Le livre de l'algèbre et le problème des asymptotes de Simon Moto”. *Revue des études juives* 27 (1893), 91-105; 28 (1894), 228-246; 29 (1895), 11-126.

Presentation and French translation of two texts written in Hebrew by a Italian, Jewish scholar of the XVth century, a friend of Mordekhai Finzi. The first text deals with equations of the second degree, or reducible to the second degree, which are given in “the books of Christians”. The second text deals with the asymptotic property of the hyperbola.

1633. Sarfatti, Gad B. “Numerical Fractions in Biblical and Rabbinical Literature”. *Tarbiṣ* 28 (1959), 1-17. In Hebrew.

1634. Sarfatti, G. B. *Mathematical Terminology in Hebrew Scientific Literature of the Middle Ages.* Jerusalem: Magnes Press, 1968, 265 pp. In Hebrew with English summary.

A discussion of the development of Hebrew scientific terms in ancient and medieval times starting with the Bible and the Talmud. The authors whose works are most extensively treated are: Abraham Bar Ḥiyya, Abraham Ibn Ezra, Maimonides, Moses Ben Tibbon, Isaac Israeli, and Levi ben Gerson. There is also a chapter on Hebrew translations with examples from Euclid, Nicomachus of Gerasa, and Archimedes. Terms in arithmetic and geometry are dealt with exhaustively, whereas trigonometry and mathematical astronomy receive less attention. Distinctions are made among various methods for enlarging the stock of scientific terms, including the modification of the meaning of an earlier word, semantic borrowing, and introducing foreign words. An extensive index is provided.

1635. Schub, Pincus. “A Mathematical Text by Mordecai Comtino”. *Isis* XVII (1932), 54-70.

Presentation of a mathematical composition drawn up in the XVth century, in Constantinople. Large extracts of this text are translated into German in Moritz Silberberg, “Ein handschriftliches hebräisch-mathematisches Werk des Mordechai Comtino”, *Jahrbuch der Jüdisch-Literarischen Gesellschaft* III (1905), 277-292; IV (1906), 214-237.

1636. Steinschneider, M. *Mathematik bei den Juden*. 2nd ed., with an index by A. Goldberg. Hildesheim: George Olms, 1964, 221 pp.

Originally published as a series of articles (1893–1901). In this study the author lists in chronological order Jewish mathematicians and astronomers who wrote primarily in Hebrew. Some biographical remarks and a description of their works, mostly unpublished, are based on Steinschneider's own investigations of the manuscript sources. This bibliographic work sets a very high standard for the history of medieval science.

1637. Steinschneider, M. "Mathematik bei den Juden (1551–1840)". *Monatsschrift für Geschichte und Wissenschaft des Judentums* 49, Neue Folge 13 (1905), 78–95, 193–204, 300–314, 490–498, 581–605, 722–743.

A continuation of item 1636. Due to the author's death, the discussion does not go beyond the end of the eighteenth century.

1638. Steinschneider, M. *Die hebraeischen Übersetzungen des Mittelalters und die Juden als Dolmetscher*. Berlin: Kommissionsverlag des Bibliographischen Bureaus, 1893, 1112 pp.

The basic bibliographic source for translations of scientific and philosophical texts into Hebrew in the Middle Ages. It is arranged by subject and divided into sections on Christian, Muslim, and Jewish authors. In addition to extensive references to manuscripts, both published and unpublished, there are summaries of the contents of the texts.

1639. Steinschneider, Moritz. "Brani dell'Arithmetica d'Elia Misrachi tradotti dall'ebraico". In *Lettera IV di M. Steinschneider a D. B. Boncompagni.* Rome, 1866, 43-67.

Extracts, translated with commentary, in Italian of the *Arithmetic* of E. Mizraḥi, written in Constantinople at the beginning of the XVIth century, and printed in 1534. Part of the work was summarized and translated into Latin in 1547. The first study of it as a whole is proposed in Gustav Wertheim,*Die Arithmetik des Elia Mizrachi. Ein Beitrag zur Geschichte der Mathematik*, Braunschweig, 1896.

1640. Wolfson, H. A. "The Classification of Sciences in Medieval Jewish Philosophy". *Hebrew Union College Jubilee Volume*. Cincinnati: Hebrew Union College, 1925, 263–315. "Additional Notes". *Hebrew Union College Annual* 3 (1926), 371–375.

The classification of the sciences was traditionally attributed to Plato and Aristotle, and the schemes found in Jewish literature reflect the Arabic versions of these traditions. The classifiers whose schemes are treated include Isaac Israeli, al-Mukammas, Baḥya ibn Pakuda, Abraham Ibn Ezra, and, especially, Maimonides. It is worth noting that al-Ghazali, Abraham Ibn Ezra, and Afendopolo put astrology under physics, while Abraham Bar Ḥiyya, Falaquera, and Rieti made it coordinate to astronomy and put it under mathematics.

1641. Zuckermann, Benedict. *Das Mathematische im Talmud*. Breslau, 1878.

A very useful synthesis because of its detailed references and analyses.

Works on Individual Mathematicians

Abraham bar Ḥiyya (died ca. 1136)

The texts by Abraham bar Ḥiyya have been edited and translated into Spanish by J. M. Millás Vallicrosa. See item 1624.

1642. Levey, Martin. "Abraham Savasorda and His Algorithm: A Study in Early European Logistic". *Osiris* 11 (1954), 50–64.

1643. Levey, Martin. "The Encyclopedia of Abraham Savasorda: A Departure in Mathematical Methodology". *Isis* 43 (1952), 257–264.

Abraham Ibn Ezra (1089–1164)

1644. Ginsburg, J. "Rabbi ben Ezra on Permutations and Combinations". *The Mathematics Teacher* 15 (1922), 347–356.

1645. Silberberg, Moritz. *Sefer ha-Mispar. Das Buch der Zahl ein hebraisch-arithmetisches Werk des R. Abraham ibn Ezra*. Halle a. S.: C. A. Kaemmerer & Co., 1891.

Crescas (died 1412)

1646. Rabinovitch, Nachum L. "Rabbi Hasdai Crescas (1340–1410) and Numerical Infinities". *Isis* 61 (1970), 222–230.

The reader should also consult Tony Lévy, *Figures de l'infini. Les mathématiques au miroir des cultures*, Paris, 1987, ch.V, section 5: "Théologie de l'infini contre science d'Aristote: Hasdai Crescas (1340-1412) critique de Maïmonide, 187-208. "

Delmedigo, Yoseph Shlomo (1591-1655)

1647. Heilbronn, Isak. *Die mathematischen und naturwissenschaftlichen Anschauungen des Josef Salomo Medigo*. Erlangen, 1913.

The Jewish scholar, Delmedico, of Cretan origin, who perhaps met Galileo in Italy, has left several mathematical writings, in particular on spherical trigonometry, which have not yet had a proper historical analysis.

Finzi, Mordecai (fl. ca. 1460)

1648. Langermann Tzvi,Y. "The Scientific Writings of Mordekhai Finzi". *Italia: Studi e ricerce sulla storia, la cultura e la letteratura degli ebrei d'Italia* 7 (1988), 7-44.

The author presents the writings (for the most part still in manuscript form) on mathematics and astronomy of the Jewish scientist and translator from Mantova in the XVth century.

1649. Levey, Martin. *The Algebra of Abū Kāmil in a Commentary by Mordecai Finzi.* Hebrew text with English translation and a commentary, with foreword by Marshall Clagett. Madison: University of Wisconsin Press, 1966.

An example of the work of Hebrew translators in preserving and transmitting mathematical science from East to West.

Immanuel Tov-Elem (Bonfils) (14th Century)

1650. Gandz, Solomon. "The Invention of the Decimal Fractions and the Application of the Exponential Calculus by Immanuel Bonfils of Tarascon (c. 1350)". *Isis* 25 (1936), 16–45.

See item 1598 above.

However, the origin of decimal fractions is placed much earlier by the following two authors.

1651. Rabinovitch, Nachum L. "An Archimedean Tract of Immanuel Tov-elem (14th Century)". *Historia Mathematica* 1 (1974), 13–27.

1652. Rashed, Roshdi. "L'extraction de la racine $n^{\text{ième}}$ et l'invention des fractions décimales (XIe–XIIe siècles)". *Archive for History of Exact Sciences* 18 (1978), 191–243.

Levi ben Gerson

(1288–1344)

1653. Carlebach, J. *Levi ben Gerson als Mathematiker.* Berlin: L. Lamm, 1910.

Includes the Latin text of *De Numeri harmonicis.*

1654. Curtze, M. "Die Abhandlung des Levi ben Gerson über Trigonometrie und den Jacobstab". *Bibliotheca Mathematica* (1898), 77–112.

1655. Curtze, M. "Urkunden zur Geschichte der Trigonometrie im Christlichen Mittelalter". *Bibliotheca Mathematica* (1900), 321–416.

1656. Espenshade, P. H. "A Text on Trigonometry by Levi ben Gershon". *The Mathematics Teacher* 60 (1967), 628–637.

Based on Curtze (item 1655) as well as manuscripts in Latin and Hebrew in an English translation.

1657. Goldstein, Bernard R. "The Astronomical Tables of Levi ben Gerson". *Transactions of the Connecticut Academy of Arts and Sciences* 45 (1974), 1–285.

See item 1599 above.

1658. Lange, G. *Sefer Maasei Choscheb. Die Praxis der Rechners, ein hebraisch-arithmetisches Werk des Levi ben Gerschom aus dem Jahre 1321.* Frankfurt am Main: n.p., 1909.

1659. Rabinovitch, Nachum L. "Rabbi Levi ben Gershon and the Origins of Mathematical Induction". *Archives for History of Exact Sciences* 6 (1970), 237–248.

Contains a translation of some theorems in Levi's *Maasei Hoshev*, mainly on combinations and permutations, as well as earlier work on this subject by Shabbetai ben Abraham Donnolo (913–970).

Māshā'allah (Menasheh ben Athan) (754–813)

See item 1770, in which two chapters on stereographic projections from Māshā'allah's *Treatise on the Astrolabe* are translated into English. Recent scholarship has argued, however, that the Arabic original of this Latin text on the astrolabe ascribed to Māshā'allah is probably due to al-Majriti (a Spanish Muslim, d. 1007) or his school: cf. P. Kunitzsch, *Typen der Sternverzeichnissen...* (Wiesbaden: O. Harrassowitz, 1956), 7. The entire text also appears in R. T. Gunther, *Chaucer and Mesella on the Astrolabe* (Oxford: Oxford University Press, 1929).

Zacut, Abraham (1452–ca. 1530)

1660. Cantera Burgos, F. *Abraham Zacut.* Madrid: M. Aguilar, 1935, 225 pp.

A biography and description of Zacut's works as well as a bibliography and selections from his astronomical and astrological treastises. Zacut lived in Spain until 1492 and then traveled to Portugal, North Africa, and Palestine. His best known scientific work is a set of astronomical tables written in Hebrew (*Ha-ḥibbur ha-gadol*) and translated into Latin (*Almanac Perpetuum*, Leiria, 1496; reprinted Berne, 1915), Arabic, Spanish, and Ladino. He was consulted by Vasco da Gama before his voyage to India and he influenced a number of later figures including his pupils Vizinho and Ricius, and Abraham Gascon (16th century, Cairo). For the most recent study of his work, see B. R. Goldstein, "The Hebrew Astronomical Tradition: New Sources", *Isis* 72 (1981), 237–251.

LATIN WEST

The boundaries of medieval Latin mathematics are difficult to define. A large part of medieval mathematics consists of the use and adaptation of earlier mathematical works. Consequently, the following bibliography includes a number of items concerning the medieval Latin versions of Euclid or Archimedes or of various Islamic mathematicians and so forth. Thus medieval Latin mathematics cannot be strictly separated from Greek, Islamic, or Hebrew mathematics. Another problem concerns how widely the net should be cast among medieval Latin works. In medieval divisions of the sciences, mathematics is often taken to include not only arithmetic and geometry, but also astronomy and music, i.e., all of the so-called quadrivium. Since much of the more complicated medieval mathematics and much of the more sophisticated use of mathematics in the Middle Ages occurred as a part of astronomy, one cannot obtain a balanced view of medieval mathematics without considering mathematical astronomy. Medieval musical treatises cast important light on the medieval conception of ratio, which may otherwise be less easily understandable. If one includes mathematical astronomy and music as parts of mathematics, then there is a temptation to include also the so-called *scientia mediae* or sciences half-way between mathematics and physics, such as optics, statics or the science of weights, and, later, kinematics and dynamics. There are also medieval philosophical discussions of concepts that may be considered mathematical, such as the concepts of infinity and continuity or of indivisibles. The following listings are more complete for mathematics more narrowly defined than for these other areas, but a selection of works concerning the broader areas has also been included.

Catalogues and Reference Works

1661. Jayawardene, S. A. "Western Scientific Manuscripts before 1600: A Checklist of Published Catalogues". *Annals of Science* 35 (1978), 143–172.

A bibliography of catalogues of scientific manuscripts.

1662. Lutz, L., et al. *Lexikon des Mittelalters*. Vols. 1–5, Munich / Zurich: Artemis-Verlag; vol. 6, Munich / Zurich: Artemis and Winkler; vols. 7–9, Munich: LexMA-Verlag, 1977–98.

See article on mathematics by M. Folkerts and E. Neuenschwander as well as articles on individual mathematicians including Boethius, Gerbert, Fibonacci, Pacioli, Bradwardine, Oresme, Jordanus Nemorarius, Adelard of Bath, Albert of Saxony, Leon Battista Alberti, Albertus Magnus, and Alcuin.

1663. Thorndike, Lynn, and Pearl Kibre. *A Catalogue of Incipits of Mediaeval Scientific Writings in Latin*. Rev. ed. (Mediaeval Academy of America

Publications 29.) London: Mediaeval Academy of America, 1963. 1938 columns.

Fundamental reference work for the medievalist. Mathematical manuscripts may be located with the help of the name/subject index (cc. 1717–1938). Subject headings include: abacus, algorismus, arithmetic, astrolabe, calendar, computus, geometry, Euclid, measure, motion, number, proportion, quadrant, sphere.

The census of Latin mathematical manuscripts of the Middle Ages begun by Axel Anthon Bjørnbo (1874–1911) was interrupted by his untimely death. His index (some 1600 cards) is now at the Academy of Sciences in Stockholm. For details of his studies in codicology see Menso Folkerts, "Der Nachlass Axel Anthon Björnbos", *Historia Mathematica* 5 (1978), 333–339. Dorothea Waley Singer's "Handlist of Western Scientific Manuscripts in Great Britain and Ireland Dating from Before the Sixteenth Century", compiled in 1920 (card index in boxes arranged by subject, including: astronomy, calendar, computus, mathematics, measures and weights) has been deposited in the British Library, Department of Manuscripts. (There are microfilm copies at the Library of Congress, Washington, and the Warburg Institute, London.)
Warren Van Egmond's *Practical Mathematics in the Italian Renaissance: A Catalog of Italian Abbacus Manuscripts and Printed Books to 1600* catalogs some 400 abbacus manuscripts (item 1922). Some articles and books on mathematical manuscripts of special libraries or collections: Guy Beaujouan, *Manuscrits scientifiques médiévaux de l'Université de Salamanque et de ses 'Colegios Mayores'*, Bordeaux, Féret & Fils, Éditeurs, 1962; M. Folkerts, "Mittelalterliche mathematische Handschriften in westlichen Sprachen in der Herzog August Bibliothek Wolfenbüttel. Ein vorläufiges Verzeichnis", *Centaurus* 25 (1981), 1-49; M. Folkerts, "Mittelalterliche mathematische Handschriften in westlichen Sprachen in der Berliner Staatsbibliothek. Ein vorläufiges Verzeichnis", *Mathematical Perspectives*, ed. J. Dauben, New York, (1981), 53-93; W. Kaunzner, *Über die mittelalterlichen mathematischen Handschriften der Staats- und Stadtbibliothek Augsburg*, München: Deutsches Museum, (1983).

Other projects to collect and catalogue information about medieval mathematical manuscripts are being conducted by Menso Folkerts of the Ludwig-Maximilians-Universität München (see *Historia Mathematica* 10 [1983], 98–99) and by Laura Toti Rigatelli and Raffaella Franci of the Centro Studi della Matematica Medioevale of the University of Siena.

General Textbooks

1664. Cantor, Moritz B. *Vorlesungen über Geschichte der Mathematik.* Leipzig: Teubner, 1880–1908. 4 vols.

Cantor was one of the leading historians of mathematics in Germany at the turn of the century. He is best known for the once highly praised *Vorlesungen* which, despite many contemporary emendations, has not been equaled in content and extent. Although now dated, it is still informative on the subject of medieval mathematics, and gave a definite impetus to the development of the history of mathematics in general as a scholarly discipline. See also items 891, 1154, 1871.

1665. Gericke, Helmuth. *Mathematik im Abendland. Von den römischen Feldmessern bis zu Descartes.* Berlin: Springer-Verlag, 1990. xiv + 352 pp.

A general description of the development of mathematics in Western Europe from Roman times to Descartes, with special emphasis on the medieval West.

1666. Juschkewitsch, Adolf P. *Geschichte der Mathematik im Mittelalter.* Leipzig: B. G. Teubner, 1964. Originally published in Russian as *Istoriia matematiki v srednie veka.* Moscow: Fizmatgiz, 1961.

The author's research, as well as other extensive studies of medieval mathematics, were systematized and generalized in this book (first Russian edition 1961; revised German translation 1964; French translation of part 3 on Arab mathematics, with added notes by the author, 1976). A systematic exposition of enormously rich material, this work is also a source of new ideas on medieval mathematics. It provides an up-to-date account of the history of medieval mathematics in China, India, Arabia, and Europe. See also item 1231.

1667. Lindberg, David, ed. *Science in the Middle Ages.* Chicago, London: University of Chicago Press, 1978.

Contains an excellent survey of medieval mathematics by Michael S. Mahoney as well as chapters on cognate fields such as astronomy, the science of weights, the science of motion, and optics. The Mahoney chapter is especially recommended for putting the mathematics into its medieval context. The chapter by Olaf Pedersen on astronomy should be used to supplement this bibliography with regard to mathematical astronomy.

1668. Sarton, George. *Introduction to the History of Science.* Baltimore: Williams and Wilkins, 1927–1948. 3 vols.

Fundamental source for outline biographies and associated bibliographies. Volume I covers the beginnings through the eleventh century. Volume II in two parts covers the twelfth and thirteenth centuries. Volume III in two parts covers the fourteenth century.

1669. Tropfke, Johannes. *Geschichte der Elementarmathematik*. Vol. 1. *Arithmetik und Algebra*. 4th ed. Vollständig neu bearbeitet von Kurt Vogel, Karin Reich, Helmuth Gericke. Berlin, New York: Walter de Gruyter, 1980, 724 pp.

This was to be the first of a completely revised three-volume edition (the others to be devoted to geometry and analysis) of Tropfke's classic work on elementary mathematics. The first edition appeared in 1902, and the third between 1930 and 1940. This edition introduces a new structure to the text to improve the ease of use. Substantially more detail than in earlier editions is given in the section on the applied art of reckoning. Also, an index to people and subjects is provided, as well as an updated bibliography. Subjects include: number theory, numeration, algebra, and recreational mathematics. See also items 1893, 2464.

Editions of Texts

Included in this section are items consisting largely of texts, but many texts are accompanied by valuable introductions and commentaries.

The Centro Studi della Matematica Medioevale of the University of Siena has begun publishing a series of brief books, the Quaderni del Centro Studi della Matematica Medioevale, containing medieval mathematical texts. Through 1994, twenty-two of these quaderni had appeared. They follow as items 1670 to 1691.

1670. Tommaso della Gazzaia. *Praticha di geometria e tutte misure di terre dal ms. C.III.23 della Biblioteca Comunale di Siena*. Vol. 1 of series Quaderni del Centro Studi della Matematica Medioevale. Trascrizione di Cinzia Nanni, Introduzione di Gino Arrighi. 1982, 77 pp.

1671. Benedetto da Firenze. *La reghola de algebra amuchabale dal Codice L.IV.21 della Biblioteca Comunale di Siena*. Vol. 2 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Lucia Salomone. 1982, xviii + 104 pp.

1672. Bartolo, Giovanni di. *Certi chasi nella trascelta a cura di Maestro Benedetto secondo la lezione del Codice L.IV.2l (sec. XV) della Biblioteca degli Intronati di Siena*. Vol. 3 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Marisa Pancanti. 1982, ix + 107 pp.

1673. Calandri, Filippo. *Una raccolta di ragioni dal Codice L.VI.45 della Biblioteca Comunale di Siena*. Vol. 4 of series Quaderni del Centro

Studi della Matematica Medioevale. A cura e con introduzione di Daniela Santini. 1982, x + 50 pp.

1674. Biagio. *Chasi exemplari alla regola dell'algibra nella trascelta a cura di M° Benedetto dal Codice L.IV.2l della Biblioteca Comunale di Siena.* Vol. 5 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Licia Pieraccini. 1983, xv + 143 pp.

1675. Gilio. *Questioni d'algebra. Dal Codice L.IX.28 della Biblioteca Comunale di Siena.* Vol. 6 of series Quaderni del Centro Studi della Matematica Medioevale. A cura et con introduzione di R. Franci. 1983.

1676. Canacci, Raffaello. *Ragionamenti d'algebra i problemi dal Codice Pal. 567 della Biblioteca Nazionale di Firenze.* Vol. 7 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Angiolo Procissi, 1983, 93 pp.

1677. Anonimo Maestro Lombardo. *Arte Giamata Aresmetica. Un'antologia dal codice N.III.53 della Biblioteca Nazionale di Torino.* Vol. 8 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduztione di Maria Teresa Rivolo, 1983, 71 pp.

1678. Gori, Dionigi. *Libro e trattato della praticha d'alcibra dal Codice L.IV.22 della Biblioteca Comunale di Siena.* Vol. 9 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Laura Toti Rigatelli, 1984, vii, 33 pp.

1679. Leonardo Pisano. *E' chasi della terza parte del XV capitolo del Liber abaci nella trascelta a cura di Maestro Benedetto secondo la lezione del Codice L.IV.21 (sec. XV) della Biblioteca Comunale di Siena.* Vol. 10 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Lucia Salomone, 1984, xiii, 105 pp.

1680. Castellani, Gratia de'. *Chasi sopra chonpagnie dal codice Palatino 573 della Biblioteca Nazionale di Firenze.* Vol. 11 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Marisa Pancanti, 1984, xiii, 48 pp.

1681. Gori, Dionigi. *Libro Di Ragioni et Misure in sunto e a mente dal Codice L.IX.30 della Biblioteca Communale di Siena.* Vol. 12 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Raffaella Franci. 1984, xvi + ff. 41.

1682. Anonimo Senese (15th century). *Differenze di Geometria et Misure a Ochio (Da. ms. Plimpton 194 della Biblioteca della Columbia University).* Vol. 13 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Maria Teresa Rivolo. n.d., 65 pp.

1683. Dell'Abbaco, Paolo. *Pratricha d'Astorlogia dai Codici Fond. Prin. II, IX, 57 della Bibliotteca Nazionale di Firenze e Ash. 1662 della Biblioteca Laurenziana di Firenze.* Vol. 14 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Brunetto Piochi. 1985, 61 pp..

1684. Anonimo. (15th century). *Della Radice de' Numeri et Metodo di Trovarla (Trattatello di Algebra e Geometria) dal Codice Ital. 578 della Biblioteca Estense di Modena Parte Prima.* Vol. 15 of series Quaderni del Centro Studi della Matematica Medioevale. A cura di Warren Van Egmond. 1986, 127 pp.

1685. Anonimo (sec. XV). *Della radice de' numeri e metodo di trovarla (Trattatello di Algebra e Geometria) dal Codice Ital. 578 della Biblioteca Estense di Modena.* Vol. 16 of series Quaderni del Centro Studi della Matematica Medioevale. Parte seconda a cura di Francesco Barbieri e Paola Lancellotti, 1986, vi, 36 pp.

1686. Bastiano da Pisa detto il Bevilacqua (sec. XVI). *Tratato d'arismeticha praticha dal Codice Ital. 1110 della Biblioteca Estense di Modena.* Vol. 17 of series Quaderni del Centro Studi della Matematica Medioevale. A cura di Francesco e Barbieri Paola Lancellotti, without year (1992?), 83 pp.

1687. Anonimo (14th century). *Il Trattato d'Algibra dal Manoscritto Fond. Prin. II.V.152 della Biblioteca Nazionale di Firenze.* Vol. 18 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Raffaella Franci e Marisa Pancanti. 1988, 162 pp..

1688. Da Montepulciano, Orbetano. *Regole di Geometria Pratica dal manoscritto Moreni '30 (sec. XV) della Biblioteca Riccardiani di Firenze.* Vol. 19 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Annalisa Simi. 1991, 95 pp.

1689. Anonimo Fiorentino. *Regole di Geometria e della cosa dal Codice Palatina 575 (sec. XV) della Biblioteca Nazionale di Firenze.* Vol. 20

of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Annalisa Simi. 1992, 75 pp.

1690. Anonimo Fiorentino. *Trattato di Geometria Pratica dal Codice L.IV.18 (sec. XV) della Biblioteca Communale di Siena*. Vol. 21. of series Quaderni del Centro Studi della Matematica Medioevale. A cura et con introduzione di Annalisi Simi. 1993, 194 pp.

1691. Anonimo (14th century). *Trattato dell'Alcibra Amuchabile dal Codice Ricc. 2263 della Biblioteca Riccardiana di Firenze*. Vol. 22 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Annalisa Simi. 1994, 61 pp.

1692. Anonimo Fiorentino (sec. XV). *Alchuno chaso sottile. La quinta distinzione della Praticha di Geometria dal Codice Ottoboniano Latino 3307 della Biblioteca Apostolica Vaticana*. Vol. 23 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Annalisa Simi, 1999, 53 pp.

1693. Anonimo. *Algorismus dal Cod. AD. XII. 53 della Biblioteca Nazionale Braidense di Milano*. Vol. 24 of series Quaderni del Centro Studi della Matematica Medioevale. A cura e con introduzione di Gino Arrighi, 1999, 30 pp.

1694. Allard, A. *Muḥammad ibn Mūsā al-Khwārizmī Le Calcul Indien (Algorismus)*, Paris: Namur (Société des Études Classiques), 1992.

Edition of al-Khwarizmi's arithmetical text and of two texts of the 12th century which are based upon it (*Liber Ysagogarum, Liber Alchorismi*).

1695. Arrighi, G., ed. *M^o Guglielmo, vescovo di Lucca, De arithmetica compendiose tractata*. Pisa: Domus Galilaeana, 1964, 84 pp.

Arithmetic as found in the curriculum of the twelfth-century cathedral school of Lucca.

1696. Arrighi, G., ed. *Paolo Dell'Abaco. Trattato d'arithmetica*. Pisa: Domus Galilaeana, 1964, 164 pp.

Practical mathematics as taught by an independent practitioner who lived ca. 1281–1374.

1697. Baron, R. "Hugonis de Sancto Victore Practica geometrie". *Osiris* 12 (1956), 176–224.

A critical edition of this important source from the first half of the 12th century by Hugo of St. Victor.

1698. Benjamin, Francis S., Jr., and G. J. Toomer. *Campanus of Novara and Medieval Planetary Theory. Theorica planetarum.* Madison: University of Wisconsin Press, 1971.

Edition of, translation of, and commentary on the first detailed account of the Ptolemaic astronomical system to appear in the West. Biography and bibliography of Campanus (for which see also the article in the *Dictionary of Scientific Biography*, item 8).

1699. Blume, F., K. Lachmann, and A. Rudorff. *Die Schriften der römischen Feldmesser*. Berlin, 1848–1852. Reprinted Hildesheim: G. Olms, 1967.2 vols.

Despite its age, still an essential edition of the writings of Roman surveyors, with commentary.

1700. Boncompagni, B., ed. *Scritti di Leonardo Pisano*. Rome: Tipografia delle scienze matematiche e fisiche, 1857–1862. 2 vols.

A monumental edition of all of Leonardo's writings. The first volume contains the *Liber abaci* (459 pages, without notes); the second includes, among other works, the *Practica geometriae* (224 pages). See also item 2000.

1701. Bond, J. D. "Quadripartitum Ricardi Walynforde de Sinibus Demonstratis". *Isis* 5 (1923), 99–115.

Edition from a single manuscript, no notes.

1702. Bond, J. D. "Richard of Wallingford's Quadripartitum (English Translation)". *Isis* 5 (1923), 339–363.

This and the preceding item are now superseded by John North's edition, item 1761. Translation of part of the work appears in Edward Grant, *A Source Book in Medieval Science*, item 1742, pp. 188–198.

1703. Bubnov, N. *Gerberti postea Silvestri II papae opera mathematica (972–1003)*. Berlin: R. Friedländer, 1899. Reprinted Hildesheim: G. Olms, 1963.

This monumental work contains not only editions of all of Gerbert's writings related to the quadrivium, but edits numerous other mathematical texts (to the 12th century), and contains a large section on the transmission of knowledge related to surveying. The book is essential for works on medieval mathematics before Arabic-Latin translations.

1704. Burnett, C. "*Algorismi vel helcep decentior est diligentia*: the Arithmetic of Adelard of Bath and his Circle". In *Mathematische Probleme im Mittelalter: der lateinische und arabische Sprachbereich*,

(Wolfenbütteler Mittelalter-Studien, 10), ed. M. Folkerts, Wiesbaden, 1996, 221-331.

Contains an edition of the arithmetical text by Ocreatus and gives detailed information about the teaching of arithmetic in England in the 12th century. See item 1739.

1705. Burnett, C., ed. *Adelard of Bath: An English Scientist and Arabist of the Early Twelfth Century* London: Warburg Institute, University of London, 1987.

Contributions by various authors on Adelard of Bath and his work. This volume includes a list of writings written by or ascribed to Adelard and a list of manuscripts which contain these works.

1706. Burnett, C., ed. *The Introduction of Arabic Learning into England*. London: British Library, 1997.

On the interrelation of science (including mathematics) between England and the Continent, especially the translating activities in the 12th century and the introduction and reformation of the “new” mathematics and science in England.

1707. Busard, H. L. L., ed. *The Translation of the Elements of Euclid from the Arabic into Latin by Hermann of Carinthia (?), Books VII–XII*. Leiden: E. J. Brill, 1968. Reprinted (Mathematical Centre Tracts 84), Amsterdam: Mathematisch Centrum, 1977.

This publication completes the edition in *Janus* 54 (1967), 1–140, in which Books I–VI of the translation of Euclid's *Elements* ascribed to Hermann of Carinthia appeared. The single extant manuscript, Paris Bibl. Nat. Latin 16646, does not contain Books XIII–XV of the *Elements*. However, the author of the anonymous manuscript Vat. Reg. Lat. 1268, which contains Books V, VI and X–XI.4 of the *Elements* in folios 72r–113v, was acquainted with the original Hermann version. As the proofs in the Vatican manuscript which resemble Hermann's have been more fully elaborated, the Hermann version as we have it today, is in all likelihood a very succinct one. Busard has edited other Latin Euclid versions: items 1719, 1720, 1721, 1723, and 1724.

1708. Busard, H. L. L., ed. “L'algèbre au Moyen Âge: Le ‘Liber mensurationum’ d'Abu Bekr”. *Journal des Savants* (April–June 1968), 65–124.

The Arabic gromatic tradition is principally represented by two works translated into Latin in the twelfth century. The first of these is the *Liber Embadorum* of Savasorda, the second is the *Liber mensurationum* of an unknown Abū Bakr, translated into Latin by Gerard of Cremona. Abū Bakr's formulas are almost exactly the same as those of Savasorda.

1709. Busard, H. L. L., ed. "Die Vermessungstraktate Liber Saydi Abuothmi und Liber Aderameti". *Janus* 56 (1969), 161–174.

Belongs to the same category of works as the *Liber mensurationum* (see item 1637). A brief introduction is followed by transcriptions of the two works.

1710. Busard, H. L. L., ed. "Der Traktat *De isoperimetris*, der unmittelbar aus dem Griechischen ins Lateinische übersetzt worden ist". *Medieval Studies* 42 (1980), 61–88.

The Latin *De ysoperimetris* was translated in the early thirteenth century from an anonymous Greek text (cf. Pappus, *Collectio*, ed. of F. Hultsch, Vol. 3, pp. 1138–1165) and is extant in many manuscripts. It has been demonstrated that the circle is the most capacious of isoperimetric plane figures and the sphere of solid isoperimetric figures.

1711. Busard, H. L. L., ed. "Ein mittelalterlicher Euklid-Kommentar, der Roger Bacon zugeschrieben werden kann". *Archives Internationales d'Histoire des Sciences* 24 (95) (1974), 199–218.

Presents the text of a Latin manuscript, Florence, Bibl. Naz. Conv. Soppr. J. IX. 26, of a Euclid commentary formerly attributed to Adelard of Bath. The text is in an appendix.

1712. Busard, H. L. L. "Het rekenen met breuken in de Middeleeuwen, in het bijzonder bij Johannes de Lineriis". *Mededelingen van de Koninklijke Vlaasme Academie voor Wetenschappen, Letteren en Schone Kunsten van België, Klasse der Wetenschappen (Brussels)* XXX (7) (1968), 36 pp.

In the *Algorismus de minutiis* John of Lignères simultaneously treated physical and vulgar fractions. Its great success is attested to by the number of manuscripts in which it is preserved. The treatise was printed twice, together with, and after, the *Algorismus de integris* of Prosdocimus de Beldomandis. First edition Padua, 1483; second, Venice, 1540.

1713. Busard, H. L. L., "Die 'Arithmetica speculativa' des Johannes de Muris". *Scientiarum Historia* 13 (1971), 103–132.

About 1323 John of Murs wrote an arithmetic of the Boethian type. It was printed in Vienna (1515), and was a popular textbook for a considerable time (at least in the German countries).

1714. Busard, H. L. L., "Die Traktate *De proportionibus* von Jordanus Nemorarius und Campanus". *Centaurus* 15 (1971), 193–227.

The *Liber de proportionibus*, anonymous in most manuscripts, but attributed to Jordanus in one and to Thābit ibn Qurra in another, and the *Tractatus de proportione et proportionalitate*, attributed to Campanus in two manuscripts, to Alkindi in two others and to Ametus filius Iosephi in another one, are concerned with the eighteen cases of six quantities in proportion where the ratio of one quantity to another is composed of ratios of the four remaining quantities. Campanus's Propositions 2 and 3 are essentially the same as Propositions 2 and 3 of the Jordanian text and Proposition 1.13 of Witelo's *Perspectiva*.

1715. Busard, H. L. L., "The *Practica geometriae* of Dominicus de Clavasio". *Archive for History of Exact Sciences* 2 (1965), 520–575.

The *Practica* was a popular work during the Middle Ages and has survived in numerous manuscript versions. It served as a model for a *Geometriae culmensis*, written in both Latin and German near the end of the 14th century. The *Practica* was composed in 1346 and is divided into an introduction and three books.

1716. Busard, H. L. L., ed. *Nicole Oresme Quaestiones super geometriam Euclidis*. Leiden: E. J. Brill, 1961.

Oresme's *Quaestiones* concentrate their attention on four not especially Euclidean, but typically scholastic, subjects: (1) mathematics and the infinite, in particular, infinite convergent and divergent series, (2) the notions of commensurability and incommensurability, (3) the Oresmian speciality of the "graphic" representation of intensible and remissible forms or the geometry of qualities, and (4) the nature and continuity properties of angles. See also the review with corrections by Murdoch, John, *Scripta mathematica* 27 (1964), 67–91.

1717. Busard, H. L. L., ed. "Der *Tractatus proportionum* von Albert von Sachsen". *Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften* (Vienna), 116, Part 2 (1971), 43–72.

The *Tractatus proportionum* is divided into two parts, the first of which deals with proportions and is dependent upon the *Tractatus de proportionibus* of Bradwardine. The second part deals with speeds and other mechanical problems. This book was quite popular and provides the skeleton for the much longer treatise *De proportionibus velocitatum in motibus* of Symon de Castello.

1718. Busard, H. L. L., ed. "Der *Traktat De sinibus, chordis et arcubus* von Johannes von Gmunden". *Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften* (Vienna), 116, Part 3 (1971), 74–113.

A treatise on the computation of sines and chords. His point of departure is an arc of 15° called a *kardaga*. Peurbach's *Tractatus super propositiones Ptolemaei de sinibus et chordis* is an abbreviated version of John's work.

1719. Busard, H. L. L., ed. *The First Latin Translation of Euclid's Elements Commonly Ascribed to Adelard of Bath.* Toronto: Pontifical Institute of Mediaeval Studies, 1983.

Edition of Adelard's translation from the Arabic, commonly called 'Adelard I'.

1720. Busard, H. L. L., ed. *The Latin translation of the Arabic version of Euclid's Elements Commonly Ascribed to Gerard of Cremona.* Leiden: New Rhine Publishers, 1983.

1721. Busard, H. L. L., ed. *The Mediaeval Latin Translation of Euclid's Elements Made Directly from the Greek.* Stuttgart: Franz Steiner Verlag, 1987.

1722. Busard, H. L. L., ed. *Jordanus de Nemore, De Elementis Arithmetice Artis. A Medieval Treatise on Number Theory.* Stuttgart: Franz Steiner Verlag, 1991, 2 vols.

An important text by one of the foremost medieval Latin mathematicians.

1723. Busard, H. L. L. and Menso Folkerts, eds. *Robert of Chester's (?) Redaction of Euclid's Elements, the so-called Adelard II Version.* Basel: Birkhäuser Verlag, 1992. 2 vols.

1724. Busard, H. L. L., ed. *A Thirteenth-Century Adaptation of Robert of Chester's Version of Euclid's Elements.* München: Institut für Geschichte der Naturwissenschaften, 1996.

A hitherto unknown reworking from the beginning of the 13th century, upon which the version ascribed to Albertus Magnus is based.

1725. Busard, H. L. L., ed. *Johannes de Muris, De arte mensurandi.* Stuttgart: Franz Steiner Verlag, 1998.

1726. Clagett, Marshall. *Archimedes in the Middle Ages.* Vol. 1. Madison: University of Wisconsin Press, 1964; Vols. 2 (2 parts), 3 (4 parts in 3), 4 (2 parts), 5 (5 parts). Philadelphia: American Philosophical Society, 1976, 1978, 1980, 1987.

Includes editions and translations of all the known Latin Archimedean texts stemming from the twelfth century through 1565. Vol. 5 contains "Quasi-Archimedean geometry in the 13th century including the *Liber de motu* of Gerard of Brussels, the *Liber philotegni* of Jordanus de Nemore, together with its longer version known as the *Liber de triangulis Iordani.*" Essential and fundamental work. See also item 1279.

1727. Clagett, Marshall. "The *Liber de motu* of Gerard of Brussels and the Origins of Kinematics in the West". *Osiris* 12 (1956), 73–175.

An edition and translation of what is in many ways the most impressive medieval work of mathematical physics, accomplishing the equivalent of an integration of velocities over the parts of rotating lines, planes, and bodies of various shapes in order to determine their average velocities. For a necessary correction to Clagett's interpretation see Wolfgang Breidert, *Das aristotelische Kontinuum in der Scholastik*, item 1790, pp. 49–61, or Edith Sylla, *The Oxford Calculators and the Mathematics of Motion, 1320–1350. Physics and Measurement by Latitudes* (unpublished Ph.D. dissertation, Harvard University, 1970 and Harvard Dissertations in the History of Science, New York: Garland Press, 1991), Appendix B. Re-edited by Clagett in *Archimedes in the Middle Ages*, Vol. 5, item 1726.

1728. Clagett, Marshall, ed. *Nicole Oresme and the Medieval Geometry of Qualities and Motions. A Treatise on the Uniformity and Difformity of Intensities Known as Tractatus de configurationibus qualitatum*. Madison: University of Wisconsin Press, 1968.

Definitive edition, translation, and commentary upon the work in which Oresme most fully developed his theory of the configurations of qualities, providing two-dimensional representations of linear qualities and analyzing these representations geometrically. Reviewed in item 1835. See also item 3034.

1729. Clagett, Marshall. *The Science of Mechanics in the Middle Ages*. Madison: University of Wisconsin Press, 1959; 2nd printing, 1961.

A collection of texts covering statics, kinematics, and dynamics, with English translations most prominent, but including also general introductions, Latin texts, and commentaries. Shows the extent and limitations of the use of mathematics in these areas during the Middle Ages. See also item 1227.

1730. Crosby, H. Lamar, Jr. *Thomas of Bradwardine. His Tractatus de Proportionibus. Its Significance for the Development of Mathematical Physics*. Madison: University of Wisconsin Press, 1955; 2nd printing 1961.

Edition and translation of a highly influential work applying the theory of ratios to dynamics.

1731. Curtze, Maximilian. *Der Algorismus Proportionum des Nicolaus Oresme; zum ersten Male nach der Lesart der Handschrift R.* 4°*.2. der königlichen Gymnasialbibliothek zu Thorn herausgegeben*. Berlin: J. Draeger (C. Feicht), 1868.

Important for understanding the effect of notation and methods of manipulation on medieval conceptions of ratio. Part I of the work re-edited on the basis of thirteen manuscripts in Edward Grant, "The Mathematical Theory of Proportionality of Nicole Oresme", Ph.D. dissertation, University of Wisconsin, 1957, 331–339. Partial English translation by Edward Grant, *Isis* 56 (1965), 335–341, and in *A Source Book in Medieval Science*, item 1742, pp. 150–157.

1732. Curtze, Maximilian, ed. *Anaritii in decem libros priores Elementorum Euclidis commentarii*. Leipzig: Teubner, 1899, 1–252.

A commentary on Books I–X of the *Elements* of Euclid (incomplete [?]) in the Latin translation of Gerard of Cremona. A large number of extracts of Geminus's and Heron's *Commentary on Euclid's Elements* are included.

1733. Curtze, Maximilian. "Der *Liber Embadorum* des Savasorda in der Übersetzung des Plato von Tivoli". In *Urkunden zur Geschichte der Mathematik im Mittelalter und der Renaissance.* Leipzig: Teubner, 1902; also *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 12 (1902), 1–183.

Savasorda's most influential work by far is his Hebrew treatise on practical geometry, the *Ḥibbūr ha-meshīḥah we-ha-tish-boret*, translated into Latin as *Liber Embadorum* by Plato of Tivoli in 1145. The *Liber Embadorum* is the earliest exposition of Arab algebra written in Europe, and it contains the first complete solution in Europe of the quadratic equation. The *Ḥibbūr* was also among the earliest works to introduce Arab trigonometry and mensuration into Europe and influenced Leonardo Fibonacci who devoted an entire section of his *Practica geometriae* to division of figures.

1734. Elie, Hubert. *Le traité "De l'infini" de Jean Mair*. Paris: J. Vrin, 1938.

Edition and translation of a scholastic treatise asking whether there is an infinite in act and whether God can produce an infinite in act. Uses arguments concerning proportional parts, spiral lines, diagonals, angles, etc.

1735. Folkerts, M. "Pseudo-Beda: *De arithmeticis propositionibus*, eine mathematische Schrift aus der Karolingerzeit". *Sudhoffs Archiv* 56 (1972), 22–43.

A critical edition (with commentary) of the text (in existence in the 8th century), which among other things treats negative numbers.

1736. Folkerts, M. *Die älteste mathematische Aufgabensammlung in lateinischer Sprache: Die Alkuin zugeschriebenen Propositiones ad acuendos iuvenes. Überlieferung, Inhalt, Kritische Edition. Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften*, 116, Part 6 (1978).

A critical edition of the oldest collection of mathematical exercises, attributed to Alcuin.

1737. Folkerts, M. *"Boethius" Geometrie II, ein mathematisches Lehrbuch des Mittelalters*. Wiesbaden: Steiner, 1970.

A critical edition of the geometry (in two books) ascribed to Boethius, with extensive notes to its contents and textual tradition. Euclidean quotations in other works taken from the translation by Boethius are also edited here.

1738. Folkerts, M., and A. J. E. M. Smeur. "A Treatise on the Squaring of the Circle by Franco of Liège of about 1050". *Archives Internationales d'Histoire des Sciences* 26 (1976), 59–105, 225–253.

1739. Folkerts, M. *Mathematische Probleme im Mittelalter: der lateinische und arabische Sprachbereich*, (Wolfenbütteler Mittelalter-Studien, 10), ed. M. Folkerts, Wiesbaden: Harrassowitz, 1996.

Papers of a congress on medieval Western and Eastern science (including mathematics) which was held in Wolfenbüttel in 1990. The following contributors to the meeting dealt with mathematics (and not astronomy): George Molland, Jan P. Hogendijk, Yvonne Dold-Samplonius, Ahmed Djebbar, Sonja Brentjes, H. L. L. Busard, Richard Lorch, Barnabas Hughes, Charles Burnett, Wilbur R. Knorr, Jacques Sesiano, Warren Van Egmond, Wolfgang Kaunzner. All of them, with the exception of Hogendijk and Djebbar, dealt with Western medieval mathematics.

1740. Grant, Edward. *Nicole Oresme and the Kinematics of Circular Motion. Tractatus de commensurabilitate vel incommensurabilitate motuum celi.* Madison: University of Wisconsin Press, 1971.

Edition and translation of a text in which Oresme attempts to undermine predictive astrology by showing that the motions of the heavens are probably incommensurable. His argument is based ultimately upon Bradwardine's theory of ratios of motions and on his own exension of that theory. Extensive introductory analysis.

1741. Grant, Edward. *Nicole Oresme: De proportionibus proportionum and Ad pauca respicientes.* Madison: University of Wisconsin Press, 1966.

The most important source for Oresme's theory of the ratios of ratios. An earlier version of some of the same material is in "Nicole Oresme and His *De proportionibus proportionum*", *Isis* 51 (1960), 293–314.

1742. Grant, Edward, ed. *A Source Book in Medieval Science.* Cambridge, Mass.: Harvard University Press, 1974.

Contains English translations of eighteen short mathematical texts. Selections from Isidore of Seville, Boethius, Roger Bacon, Jordanus de Nemore, al-Khwārizmī, Leonardo of Pisa, Nicole Oresme, Campanus of Novara, Pseudo-Bradwardine, Albert of Saxony, the Banū Mūsā, Dominicus de Clavasio, and Richard Wallingford. Approximately 130 pages in all. Good place to start.

1743. Guillaumin, Jean-Yves. *Boèce. Institution arithmétique.* Paris: Les Belles Lettres, 1995.

Edition and French translation of Boethius's treatise on arithmetic.

1744. Hahn, F. Nan. *Medieval Mensuration: Quadrans Vetus and Geometrie Due Sunt Partes Principales* . . . (Transactions of the American Philosophical Society, Vol. 72, part 8.) Philadelphia: American Philosophical Society, 1982.

1745. Halliwell, J. O. *Rara mathematica.* 1. *Joannis de Sacro-Bosco Tractatus de arte numerandi.* London, 1841. Reprinted Hildesheim: Olms, 1977.

Includes also "A Method Used in England in the Fifteenth Century for Taking the Altitude of a Steeple or Other Inaccessible Object," and other treatises on algorism.

1746. Hughes, Barnabas. *Regiomontanus on Triangles. De triangulis omnimodis by Johann Müller, Otherwise Known as Regiomontanus.* Madison: University of Wisconsin Press, 1967.

Written in 1464 and first published in 1533, this work represents a "uniform foundation and a systematic ordering of trigonometric knowledge". Photomechanical reproduction of the original Latin with English translation and notes. See also item 2031.

1747. Hughes, Barnabas. *Jordanus de Nemore: De numeris datis.* Berkeley: University of California Press, 1981.

1748. Hughes, Barnabas. "Gerard of Cremona's Translation of al-Khwārizmī's *al-jabr*: A Critical Edition". *Mediaeval Studies* 48 (1986), 211–263.

1749. Hughes, Barnabas. *Robert of Chester's Latin Translation of al-Khwārizmī's al-jabr: A New Critical Edition.* Stuttgart: Franz Steiner Verlag, 1989.

This edition supersedes that by Karpinski (item 1753) but does not contain an English translation.

1750. Hugo of St. Victor. *Practical Geometry (Practica geometricae) Attribued to Hugh of St. Victor.* Frederick A. Homann, ed. Milwaukee, Wis.: Marquette University Press, 1991, iii + 96 pp.

An English translation of the 12th century Latin text 1697 (which was issued separately, together with additional texts, in 1966 by the University of Notre Dame Press), with a 30-page introduction on the complex history of practical geometry, including a chronological table covering the period from 300 B.C. to 1785 A.D.

1751. Hugonnard-Roche, Henri. *L'Oeuvre Astronomique de Themon Juif Maître Parisien du XIV^{e} Siècle*. Geneva: Droz, and Paris: Minard, 1973.

Discusses an interesting use of the mathematical techniques usually associated with medieval terrestrial mechanics in discussing the motion of the moon. Edits Themon's *Commentary and Questions on the Sphere of Sacrobosco and his Question on the Motion of the Moon and Other Planets* (*Utrum necessarium sit, supposita veritate theoricarum, lunam vel aliquem planetarum inequalibus gradibus [motus], vel uniformiter difformiter vel difformiter difformiter, moveri*).

1752. Ito, Shuntaro. *The Medieval Latin Translation of the Data of Euclid*. Tokyo: University of Tokyo Press, and Boston: Birkhäuser, 1980.

An edition and translation of the text with a brief introduction.

1753. Karpinski, Louis C. *Robert of Chester's Latin Translation of the Algebra of al-Khowarizmi*. (University of Michigan Studies, Humanistic Series, 11. Contributions to the History of Science, part 1.) Ann Arbor: University of Michigan Press, 1930. First published New York, 1915.

Latin text and English translation with introduction and short glossary. This edition is superseded by that of Hughes (item 1749) who, however, does not provide an English translation.

1754. Kaunzner, Wolfgang. "Über einige algebraische Abschnitte aus der Wiener Handschrift Nr. 5277". *Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften (Vienna)*, Vol. 116, Part 4 (1972), 115–184 + iv.

Contains a description of the contents of Codex Vind. Pal. 5277 and the text of some algebraic parts.

1755. L'Huillier, Ghislaine, ed. *Le Quadripartitum numerorum de Jean de Murs. Introduction et edition critique*. Geneva: Droz, 1990, 661 pp. notes, glossary.

First critical edition of John de Muris's work on arithmetic and algebra.

1756. Molland, A. G. "Roger Bacon's Geometria Speculativa". In M. Folkerts, and J. P. Hogendijk, eds. *Vestigia Mathematica. Studies in Medieval and Early Modern Mathematics in Honour of H. L. L. Busard* . Amsterdam and Atlanta, GA.: Rodopi, 1993, 265-303.

1757. Molland, A. G. *Thomas Bradwardine Geometria Speculativa. Latin Text and English Translation with an Introduction and a Commentary.* Stuttgart: Franz Steiner Verlag, 1989.

This is a critical edition of Bradwardine's important geometrical work. As to its contents, sources and influence see Molland's article, item 1831.

1758. Moody, Ernest, and Marshall Clagett. *The Medieval Science of Weights (Scientia de Ponderibus). Treatises Ascribed to Euclid, Archimedes, Thābit ibn Qurra, Jordanus de Nemore and Blasius of Parma*. Madison: University of Wisconsin Press, 1952, 1960.

Contains editions, translations, and discussions of the major texts of medieval statics.

1759. Murdoch, John, and Edward A. Synan. "Two Questions of the Continuum: Walter Chatton (?), O. F. M. and Adam Wodeham, O. F. M." *Franciscan Studies* 25 (1966), 212–288.

Treatises reflecting the early fourteenth-century controversy over whether a continuum might be composed of indivisibles.

1760. Nikolaus von Cues. *Die mathematischen Schriften, übersetzt von Josepha Hofmann*. Leipzig: F. Meiner, 1951; Hamburg: F. Meiner, 1952. 2nd ed., 1979.

All mathematical writings (including those not previously published) are translated. The extensive introduction by J. E. Hofmann evaluates the attempts by Cusanus to square the circle. This work has also been reprinted under the following title: *Nikolaus von Kues. Die mathematischen Schriften*.

1761. North, John. *Richard of Wallingford. An Edition of His Writings with Introductions, English Translations and Commentary*. Oxford: Clarendon Press, 1976. 3 vols.

Superbly done, these volumes provide an extensive if not complete edition of Wallingford's astronomical and related mathematical works. For the more important works there are English translations. The second volume contains commentaries on the astronomical and mathematical texts, setting them into historical context. The third volume consists of numerous figures, tables, appendices, glossaries, bibliography, indices, and plates.

1762. Pedersen, Frits Saaby. *Petri Philomenae de Dacia et Petri de S. Audomaro opera Quadrivialia*. Kopenhagen: Det Danske Sprog- og Litteraturselskab, Part 1, 1983; Teil 2, 1984. Corpus philosophorum Danicorum Medii Aevi, X/1 and X/2.

In Part 1, pp. 69-165, the commentary of Petrus de Dacia is given and on pp. 167-201 the text of John of Sacrobosco's *Algorismus*.

1763. Pedersen, O. *Petrus Philomena de Dacia: A Problem of Identity*. (Cahiers de l'Institut du Moyen-Âge Grec et Latin, 19.) Copenhagen: University of Copenhagen, 1976.

The identity, life and work of Petrus de Dacia, commentator on John of Sacrobosco's *Algorismus*.

1764. Picutti, Ettore. "Il Libro dei Quadrati di Leonardo Pisano e i Problemi di analisi indeterminata nel Codice Palatine 577 della Biblioteca Nazionale di Firenze". *Physis* 21 (1979), 195–339.

Contains a medieval Italian translation of Fibonacci's *Book of Square Numbers* with accompanying problems.

1765. Sigler, L. E., ed. *Leonardo Pisano Fibonacci, The Book of Squares. An Annotated Translation into Modern English by L. E. Sigler.* Boston etc.: Academic Press, 1987. xx, 124 pp.

1766. Steele, Robert, ed. *Communia Mathematica Fratris Rogeri.* (Opera hactenus inedita Rogeri Baconi, Fasc. 16.) Oxford: Clarendon Press, 1940.

Latin text with very brief editorial material. In Part I Bacon defends the importance and usefulness of mathematics and describes its various parts. In Part II he defines integers, fractions, ratios, proportionalities, and the types of mathematical demonstration.

1767. Steele, Robert, ed. *The Earliest Arithmetics in English.* London: Oxford University Press for the Early English Text Society, 1922.

Short fifteenth-century works based on the *de algorismo* of Alexander de Villa Dei and on the *de arte numerandi* of Sacrobosco. Also a work on a type of abacus from Robert Recorde's *Arithmetic* of 1543 and Alexander de Villa Dei's *Carmen de Algorismo.*

1768. Tannery, Paul. "Le traité du Quadrant de Maître Robert Anglès (Montpellier, XIII^{e} siècle). Texte latin et ancienne traduction grecque". *Notices et extraits des manuscrits de la Bibliothèque nationale* 35 561–640. Reprinted in the author's *Mémoires scientifiques* 5. Toulouse: Edouard Privat, and Paris: Gauthier-Villars, 1922, 118–197.

This work, also ascribed to Johannes Anglicus, re-edited in the dissertation of Nan Britt [Hahn], item 1744.

1769. Tannery, Paul, and M. Clerval. "Une correspondance d'ecolatres du XI^{e} siècle". *Notices et extraits des manuscrits de la Bibliothèque nationale* 36 (2) (1901), 487–543. Reprinted in the author's *Mémoires scientifiques* 5 (1922), 229–303.

Treats the discussion between Lothringian and Rheinish scholars at the beginning of the 11th century on geometrical questions.

1770. Thomson, Ron B. *Jordanus de Nemore and the Mathematics of Astrolabes: De plana spera.* Toronto: Pontifical Institute of Mediaeval Studies, 1978.

An edition, translation, and commentary on three versions of the named work with a brief history of stereographic projection and editions of related works. Contains translations of two chapters on stereographic projections from [Pseudo-]Masha'allah's *Treatise on the Astrolabe.*

1771. Tummers, P. M. J. E., ed. *Albertus (Magnus) 'Commentaar op Euclides' Elementen der Geometrie.* Nijmegen, 1984. 2 vols.

An important text for understanding the thirteenth century understanding of Euclid by a prominent Dominican philosopher.

1772. Unguru, Sabetai. *Witelonis Perspectivae Liber Primus, Book I of Witelo's Perspectiva. An English Translation with Introduction and Commentary and Latin Edition of the Mathematical Book of Witelo's Perspectiva.* (Studia Copernicana XV.) Warsaw: Ossolineum, the Polish Academy of Sciences Press, 1977.

Composed by Witelo to provide the mathematics necessary for optics, this work is a good indicator of the state of mathematical knowledge in late thirteenth-century Europe.

1773. Ver Eecke, Paul. *Léonard de Pise: de Livre des nombres carrés.* Bruges: Desclée, De Brouwer, 1952.

French translation of Leonardo Pisano's *Liber quadratorum* with notes. English translation in part in Edward Grant, *A Source Book in Medieval Science*, item 1742, pp. 114–129. See also item 1765.

1774. Victor, Stephen K. *Practical Geometry in the High Middle Ages. Artis Cuiuslibet Consummatio and the Pratike de Geometrie.* Philadelphia: American Philosophical Society, 1979.

Edition, translation, and study of the first named work and an edition of the second named work, which is a vernacular version of the first.

1775. Vogel, Kurt. *Die Practica des Algorismus Ratisbonensis.* Munich: Beck, 1954.

Vogel has not only edited the collection of exercises from St. Emmeram (Regensburg), but also goes into the origins and history of individual problems.

1776. Vogel, Kurt. *Der Donauraum, die Wiege mathematischer Studien in Deutschland.* Munich: Fritsch, 1973.

The author gives an overview of the mathematical studies in Bavaria and Austria in the late Middle Ages, and edits a calculating book (on lines), a mathematical collection of exercises, and Peurbach's writing on the calculation of the height of the sun.

1777. Vogel, Kurt. *Ein byzantinisches Rechenbuch des frühen 14. Jahrhunderts.* (Wiener byzantinistische Studien, 6). Vienna: Böhlau in Kommission, 1968.

Greek and German on opposite pages. Original manuscript in the Bibliothéque Nationale, Paris, Cod. Par. Suppl. Gr. 387. Bibliography, pp. 164–168.

1778. Zoubov, V. P. "Jean Buridan et les concepts du point au quatorzième siècle". *Medieval and Renaissance Studies* 5 (1961), 43–95.

Edits Jean Buridan's *Questio de puncto*, concerning whether points are separate entities in addition to lines.

Studies

Readers are reminded that some of the most recent and best work on biography and bibliography is to be found in *Dictionary of Scientific Biography* (item 8), especially for Leonardo of Pisa, Jordanus, Campanus, and Swineshead. For example, various nineteenth-century studies of Leonardo Pisano by Boncompagni, Woepcke, and others (not cited here for lack of space) can be readily accessed through the *Dictionary of Scientific Biography* article.

1779. Beaujouan, Guy. "L'enseignement de l'arithmétique élémentaire à l'université de Paris aux XIII^e et XIV^e siècles". In *Homenaje a Millas-Vallicrosa*. Vol. 1. Barcelona: Consejo Superior de Investigaciones Cientificas, 1954–1956, 93–124.

Extracted from his unpublished dissertation, a summary of which appears in "Recherches sur l'histoire de l'arithmétique au Moyen-Âge", *École Nationale des Chartes. Positions des thèses...de 1947* (Paris: École Nationale des Chartes, 1947), 17–22.

1780. Beaujouan, Guy. "L'enseignement du 'quadrivium' ". *Settimane di studio..., 19, La Scuola nell'Occidente latino dell'alto medioevo.* Spoleto, 1972, 639–667.

Points out that the mathematics of the early Middle Ages was relatively independent from classical texts and relied on pedagogical tools such as the monochord, the game rithmomachia, and the use of parts of the hand for computation. Argues that before the rediscovery of classical texts in the twelfth century there was little distinction between theory and practice in mathematics.

1781. Beaujouan, Guy. "Calcul d'expert en 1391, sur le chantier du Dome de Milan". *Le Moyen Âge* 69 (1963), 555–563.

Addresses the problems of the relation of theory to practice.

1782. Beaujouan, Guy. "Le symbolisme des nombres à l'époque romane". *Cahiers de Civilisation Médiévale, X–XII^e Siècles* 4 (1961), 159–169.

Discusses the influence of Boethius's *De institutione arithmetica* on ideas of the properties of numbers, numbers in the Bible, and religious number symbolism in the works of Eudes de Morimond, Guillaume d'Auberive, Geoffroy d'Auxerre, and Thibaud de Langres.

1783. Beaujouan, Guy. "Science livresque et art nautique au XV^e siècle". *Le navire et l'économie maritime travaux du cinquième colloque international d'histoire maritime tenu à Lisbonne les 14–16 Septembre*

1960. Paris: Bibliothèque générale de l'École pratique des hautes études, 1966.

Further discussion of theory and practice, this time in connection with navigation.

1784. Beaujouan, Guy. "Réflexions sur les rapports entre théorie et pratique au Moyen Âge". In *The Cultural Context of Medieval Learning*. Edited by John Murdoch and Edith Sylla. (Boston Studies in the Philosophy of Science, vol. 26.) Dordrecht: Reidel, 1975, 437–484, including discussion.

Contains an astute discussion of the relations of the medieval mathematical theory and practice, including the use of instruments.

1785. Benedict, S. R. *A Comparative Study of the Early Treatises Introducing into Europe the Hindu Art of Reckoning*. Concord, N. H.: n.p., 1914; The Rumford Press, 1916.

Based on a study of algorisms available in print.

1786. Bergmann, Werner. *Innovationen im Quadrivium des 10. und 11. Jahrhunderts. Studien zur Einführung von Astrolab und Abakus im lateinischen Mittelalter*. Stuttgart: F. Steiner Verlag, 1985.

On the invention of the so-called Gerbertian abacus.

1787. Bjørnbo, A. A. "Studien über Menelaos' Sphärik". *Abhandlungen zur Geschichte der mathematischen Wissenschaften* 14 (1902), 1–154.

Treats not only the *Spherics* of Menelaos, but is a general treatise on trigonometry in antiquity and the Middle Ages.

1788. Bond, J. D. "The Development of Trigonometric Methods down to the Close of the Fifteenth Century". *Isis* 4 (1921–1922), 295–323.

Introduction to his edition of Richard of Wallingford's *Quadripartitum*. Later in the same volume (pp. 459–465) he provides a brief biography of Wallingford, now superseded by John North's study of Wallingford, item 1761.

1789. Borst, Arno. *Das mittelalterliche Zahlenkampfspiel*. Heidelberg: C. Winter, 1986. (Supplemente zu den Sitzungsberichten der Heidelberger Akademie der Wissenschaften, Philosophisch-Historische Klasse; Jahrg. 1986, Bd. 5.)

On the history of the medieval number game, called "R(h)yt(h)momachia" (with editions of all of the earliest texts).

1790. Breidert, Wolfgang. *Das aristotelische Kontinuum in der Scholastik. Beiträge zur Geschichte der Philosophie und Theologie des Mittelalters.*

Texte und Untersuchungen. Neue Folge, Bd. 1., Münster: Aschendorff, 1970.

Valuable survey of scholastic discussions, e.g., of the continuity of reflected motions (must there be a period of rest between them?), of measures of rotations (including a good analysis of the work of Gerard of Brussels), and so forth, and of their relation to Cavalieri's method of indivisibles. See also item 1727.

1791. Busard, H. L. L. "Die Quellen von Nicole Oresme". *Janus* 58 (1971), 161–193.

An expository article discussing the sources of the works of Oresme.

1792. Busard, H. L. L. "Über den lateinischen Euklid im Mittelalter". *Arabic Sciences and Philosophy* 8 (1998), 97–129.

Summarizes Busard's views about the date and provenance of the many translations, editions, or versions of Euclid in the Latin Middle Ages. Whereas earlier historians had ascribed several versions of the Latin Euclid to Adelard of Bath (see 1794 and 1836), Busard argues for other attributions. See the footnotes in this article for other recent work in German on the Latin Euclid.

1793. Cantor, Moritz B. *Die römischen Agrimensoren und ihre Stellung in der Geschichte der Feldmesskunst.* Leipzig: B. G. Teubner, 1875.

This work indicates the connections between the Roman surveyors and Greek authors (above all, Heron). Bubnov's book, item 1703, must also be consulted for corrections and additional information.

1794. Clagett, Marshall. "The Medieval Latin Translations from the Arabic of the *Elements* of Euclid, with special emphasis on the versions of Adelard of Bath". *Isis* 44 (1953), 17–42.

Important study now available also in Clagett's collected articles, item 1795.

1795. Clagett, Marshall. *Studies in Medieval Physics and Mathematics.* London: Variorum, 1979.

A useful reprinting of thirteen articles including "The Use of Points in Medieval Natural Philosophy", "A Medieval Treatment of Hero's Theorem on the Area of a Triangle in Terms of its Sides", the previous entry (item 1794), and four articles related to the medieval Archimedean tradition.

1796. Eneström, G. "Über die 'Demonstratio Jordani de Algorismo'". *Bibliotheca Mathematica*, Series 3, 7 (1906–1907), 24–37.

Includes the Latin text of the definitions, but not the proofs. Edited from Berlin, MS. Lat. qu. 510 and Dresden, Ms. Db. 86.

1797. Eneström, G. "Über eine dem Jordanus Nemorarius zugeschriebene kurze Algorismusschrift". *Bibliotheca Mathematica*, Series 3, 8 (1907–1908), 135–153.

The introduction is printed in full along with the propositions, but only a few of the proofs are included. There is, however, a German analysis. Taken mainly from MS. Vatican, Ottob. lat. 309.

1798. Eneström, G. "Das Bruchrechnen des Jordanus Nemorarius". *Bibliotheca Mathematica*, Series 3, 14 (1913–1914), 42–44, 48–53.

The introduction and the propositions are printed in full, but the proof only of Proposition 23 is given. Taken from Vatican, MS. Ottob. lat. 309.

1799. Eneström, G. "Der 'Algorismus de integris' des Meisters Gernardus". *Bibliotheca Mathematica*, Series 3, 13 (1912–1913), 289–332.

Contains definitions, axioms, and 43 propositions. Latin text (pp. 291–327) taken from Vatican MS. Reg. lat. 1261.

1800. Eneström, G. "Der 'Algorismus de minutiis' des Meisters Gernardus". *Bibliotheca Mathematica*, Series 3, 14 (1913–1914), 99–149.

Contains definitions and 42 propositions. Latin text (pp. 100–142) taken from Vatican, MS. Reg. lat. 1261.

1801. Evans, Gillian R. "*Duc oculum*: Aids to Understanding in Some Mediaeval Treatises on the Abacus". *Centaurus* 19 (1976), 252–263.

Analyzes the pedagogical problems faced by authors of abacus treatises. See also item 3418.

1802. Evans, Gillian R. "The Rithmomachia: A Mediaeval Mathematical Teaching Aid?" *Janus* 63 (1976), 257–273.

Argues that this medieval chess-like board game was probably used as a method of teaching mathematics in eleventh- and twelfth-century schools.

1803. Evans, Gillian R. "The 'Sub-Euclidean' Geometry of the Earlier Middle Ages, up to the Mid-Twelfth Century". *Archive for History of Exact Sciences* 16 (1976–1977), 105–118.

Traces the transmission of elementary geometrical ideas in works unconnected with Euclid's *Elements*, including works on practical geometry and surveying.

1804. Evans, Gillian R. "*Difficillima et ardua*: Theory and Practice in Treatises on the Abacus c. 950–c. 1150". *Journal of Mediaeval History* 3 (1977), 21–38.

Attempts by medieval authors to elevate the study of the abacus to the status enjoyed by other arts.

1805. Evans, Gillian R. "From Abacus to Algorism: Theory and Practice in Medieval Arithmetic". *British Journal for the History of Science* 10 (1977), 114–131.

Describes the development from the use of the abacus to the use of algorism for computation during the twelfth and thirteenth centuries. The algorism reintroduces the use of a symbol for zero. At the same time astronomical fractions take over from Roman ones.

1806. Evans, Gillian R. "A Commentary on Boethius's Arithmetica of the Twelfth or Thirteenth Century". *Annals of Science* 35 (1978), 131–141.

Describes a commentary found in Munich MS. CLM 4643 that may possibly be associated with the successors of Hugo of St. Victor.

1807. Evans, Gillian R. "Introductions to Boethius's Arithmetica of the Tenth to the Fourteenth Century". *History of Science* 16 (1978), 22–41.

A description of a number of introductions which used the methods of the trivium to provide an approach to Boethius's works.

1808. Folkerts, M. *Anonyme lateinische Euklidbearbeitungen aus dem 12. Jahrhundert. Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften* (Vienna), 116, Part 1 (1971), 1–42.

This work treats various Euclidean collections between the Greek-Latin translation of Boethius and the Arabic-Latin translation ascribed to Adelard of Bath.

1809. Folkerts, M. "Mathematische Aufgabensammlungen aus dem ausgehenden Mittelalter". *Sudhoffs Archiv* 55 (1971), 58–75.

The problems discussed are in dispersed collections of mathematical exercises that were collected in the monasteries of the late Middle Ages.

1810. Folkerts, M. "Die Entwicklung und Bedeutung der Visierkunst als Beispiel der praktischen Mathematik der frühen Neuzeit". *Humanismus und Technik* 18 (1974), 1–41.

This work gives an overview of the methods used in the late Middle Ages to determine the volumes of casks; it discusses the social position of the measurers and gives a list of the printed and unprinted texts of cask measurement.

1811. Folkerts, M. "Regiomontans Euklidhandschriften". *Sudhoffs Archiv* 58 (1974), 149–164.

Regiomontanus's Euclidean manuscripts.

1812. Folkerts, M. "Die mathematischen Studien Regiomontans in seiner Wiener Zeit". (Regiomontanus-Studien). Edited by G. Hamann.

Akademie der Wissenschaften, philosophischen-historische Klasse, Sitzungsberichte (Vienna), Vol. 364 (1980), 175–209.

Unpublished and previously partially unknown texts are used to elucidate the early mathematical studies of Regiomontanus. Emphasized are arithmetic, algebra, and barrel measuring (*ars visorie*).

1813. Folkerts, Menso. "Die Bedeutung des lateinischen Mittelalters für die Entwicklung der Mathematik", in *Wissenschaftsgeschichte heute: Ansprachen und wissenschaftliche Vorträge zum 25jährigen Bestehen des Instituts für Geschichte der Naturwissenschaften, Mathematik und Technik der Universität Hamburg*, Christian Hünemörder, ed., Stuttgart: Steiner Verlag Wiesbaden, 1987, 87-114.

1814. Folkerts, Menso. *Euclid in Medieval Europe*. Winnipeg, Canada / Dunellen, N.J., U.S.A.: The Benjamin Catalogue, 1989. (Questio de rerum natura; 2.)

Lists all medieval Latin manuscripts of Euclid's *Elements*.

1815. Grant, Edward, and John E. Murdoch, eds. *Mathematics and its Applications to Science and Natural Philosophy in the Middle Ages. Essays in Honor of Marshall Clagett*. Cambridge: Cambridge University Press, 1987.

Includes Wilbur Knorr, "The Medieval Tradition of Archimedes' Sphere and Cylinder"; A. G. Molland, "Colonizing the World for Mathematics: the Diversity of Medieval Strategies"; John Murdoch, "Thomas Bradwardine: Mathematics and Continuity in the Fourteenth Century", and articles on mathematical physics.

1816. Haskins, Charles Homer. *Studies in the History of Mediaeval Science*. Cambridge, Mass.: Harvard University Press, 1924. 2nd ed. 1927. Reprinted New York: Ungar Publishing Co., 1960.

Contains fundamental studies on medieval translators from the Greek and Arabic into Latin. Also chapters on twelfth-century astronomy and on the abacus and the exchequer.

1817. Hofmann, Joseph E. *Zum Winkelstreit der rheinischen Scholastiker in der 1. Hälfte des 11. Jahrhunderts*. Berlin: W. de Gruyter, 1942.

This work on the controversy over angles among scholars of the Rhineland appeared as volume 8 in the series Abhandlungen der Preussischen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse (Berlin) 1942.

1818. Hoskin, Michael, and A. G. Molland. "Swineshead on Falling Bodies: An Example of Fourteenth Century Physics". *British Journal for the History of Science* 3 (1966), 150–182.

Representative of the extent of Swineshead's use of mathematics. See also item 1838.

1819. Hughes, Barnabas. "Biographical Information on Jordanus de Nemore up to Date". *Janus* 62 (1975), 151–156.

Review of an enigmatic subject.

1820. Kaunzner, Wolfgang. "Über den Beginn des Rechnens mit Irrationalitäten in Deutschland: Ein Beitrag zur Geschichte der Rechenkunst im ausgehenden Mittelalter". *Janus* 57 (1970), 241–260.

Discusses the period from about 1460 to the early 16th century.

1821. Kaunzner, Wolfgang. "Über einen frühen Nachweis zur symbolischen Algebra". *Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften* (Vienna), Vol. 116, Part 5 (1975), 3–12 + ii.

The author mentions the oldest (to date) known example of symbolic representations in algebra, which occurred before 1380 in Italy. See also item 2454.

1822. Kretzmann, Norman, ed. *Infinity and Continuity in Ancient and Medieval Thought.* Ithaca, N.Y.: Cornell University Press, 1982.

Contains papers covering ancient and medieval views, with contrasts between the Aristotelian tradition and anti- or quasi-Aristotelian positions.

1823. L'Huillier, Hervé. "Regards sur la formation progressive d'une langue pour les mathématiques dans l'occident médiéval". In *Comprendre et Maitriser la Nature au Moyen Âge: Mélanges d'Histoire des sciences offerts à Guy Beaujouan.* Geneva and Paris: Librairie Droz and Librairie Champion, 1994, 541-55.

1824. Lindgren, U. *Gerbert von Aurillac und das Quadrivium. Untersuchungen zur Bildung im Zeitalter der Ottonen.* Wiesbaden: Steiner, 1976.

Treats Gerbert's education and teaching, his studies of the quadrivium and his relation to the political powers of his time.

1825. Knorr, Wilbur. "John of Tynemouth 'alias' John of London: Emerging Portrait of a Singular Medieval Mathematician". *British Journal for the History of Science* 23 (1990), 293-330.

"Of primary interest for me has been the tract *De curvis superficiebus.* Written by a man identified in its heading as Johannes of Tinemue, it is a skillful synopsis, with complete proofs of the principal Archimedian theorems on the surface and volume of the sphere... In the present account, I will make proposals about this elusive character and his relation to the study of Archimedes and Euclid in the 13th century." A valiant, but not entirely successful, effort to learn more about medieval mathematical authors.

1826. Knorr, Wilbur R. "The Latin Sources of 'Quadrans Vetus,' and What They Imply for its Authorship and Date". In Edith Sylla and Michael McVaugh, eds. *Texts and Contexts in Ancient and Medieval Science*. Leiden: Brill, 1997, 23-67.

1827. Knorr, Wilbur. *Textual Studies in Ancient and Medieval Geometry*. Boston: Birkhäuser, 1989. 852 pp.

This volume attempts for the first time a complete survey of the existing evidence from antiquity on the special problems of cube duplication, angle trisection, and circle quadrature. A comparison of the various versions reveals the aims and methods of the major commentators, such as Pappus and Eutocius, and clarifies issues of authenticity and authorship. A selected set of Arabic texts on these problems is edited, with translation and commentary, in the second part. The third part assembles all the primary evidence bearing on one text, Archimedes's *Dimension of the Circle*. Greek texts and medieval translations into Arabic, Hebrew, and Latin are presented.

1828. Maddison, Francis R. "Early Astronomical and Mathematical Instruments: A Brief Survey of Sources and Modern Studies". *History of Science* 2 (1963), 17–50.

Describes medieval Europe, pp. 26–30. Long bibliography.

1829. Maier, Anneliese. *Studien zur Naturphilosophie der Spätscholastik*. Rome: Edizioni di Storia e Letteratura, 1949–1958; later editions 1966–1968. 5 vols.

In Vol. I, *Die Vorläufer Galileis im 14. Jahrhundert*, Part II concerns "Mathematisch-physicalische Fragestellungen," including the concept of function, total versus instantaneous velocity, the continuum, minima, and actual infinites. Vol. II, *Zwei Grundprobleme der scholastischen Naturphilosophie*, includes a consideration of Nicole Oresme's doctrine of the configuration of forms. In Vol. III, *An der Grenze von Scholastik und Naturwissenschaft*, Part III concerns "Die Mathematik der Formlatitudinen."

1830. Millás Vallicrosa, J. *Assaig d'història de les idées físiques i matemàtiques a la Catalunya medieval*. Barcelona: Estudis Universitaris Catalans, (sèrie monogràfica 1), 1931.

Important work on the mathematics and physics in medieval Catalan. It considers western manuscripts and Arabic sources.

1831. Molland, A. G. "An Examination of Bradwardine's Geometry". *Archive for History of Exact Sciences* 19 (1978), 113–175.

Important article concerning Bradwardine's *Geometria speculativa*. Discusses its provenance, sources, and influence, provides a synopsis of the work, characterizes Bradwardine's views of the objects and methods of geometry, of measure and ratio, and deals with the special topics of star-polygons, isoperimetry, and filling space. See also item 3057.

1832. Molland, A. G. "Ancestors of Physics". *History of Science* 14 (1976), 54–75.

Review essay on Olaf Pedersen and Mogens Pihl, *Early Physics and Astronomy: A Historical Introduction* (London: Macdonald and Jane's, New York: American Elsevier, 1974). Discusses especially the problem of mathematical translation and what can be learned by paying attention to the form in addition to the content of past theories.

1833. Molland, A. G. "Campanus and Eudoxus; or, Trouble with Texts and Quantifiers". *Physis: Rivista Internationale di Storia della Scienza* 25 (1983), 213-225.

It is generally assumed that Campanus of Novara completely misunderstood the so-called Eudoxan criterion for the equality or identity of ratios. . .but an examination of Book V of his version of Euclid's *Elements* reveals that he acquired a good understanding of how the criterion actually operated.

1834. Molland, A. G. "The Geometrical Background to the 'Merton School': An Exploration into the Application of Mathematics to Natural Philosophy in the Fourteenth Century". *British Journal for the History of Science* 4 (1968–1969), 108–125.

With Molland's other articles, one of the best introductions to medieval ratio theory as found in the work of Thomas Bradwardine.

1835. Molland, A. G. "Oresme Redivivus". *History of Science* 8 (1969), 106–118.

Essay review of Marshall Clagett, *Nicole Oresme and the Medieval Geometry of Qualities and Motions*, item 1728, with valuable insights.

1836. Murdoch, John. "Euclid: Transmission of the Elements". In *Dictionary of Scientific Biography.* Vol. 4. Edited by C. C. Gillispie. New York: Scribner's, 1971, 437–459.

Summary, with extensive notes, of the state of knowledge in 1971 concerning medieval Latin versions of Euclid's *Elements.* See also Busard's more recent study (item 1792) and his editions of Latin Euclid texts in items 1707, 1711, 1719, 1720, 1721, 1723, and 1724.

1837. Murdoch, John. "Euclides Greco-Latinus: A Hitherto Unknown Medieval Latin Translation of the Elements Made Directly from the Greek". *Harvard Studies in Classical Philology* 71 (1966), 249–302.

Describes a word-for-word translation of the *Elements* from Greek to Latin most likely made in Sicily during the twelfth century by the same unknown translators who also translated Ptolemy's *Almagest* from the Greek. This translation from Greek was edited by Busard (item 1721).

1838. Murdoch, John. "*Mathesis in Philosophiam Scholasticam Introducta.* The Rise and Development of the Application of Mathematics in Fourteenth Century Philosophy and Theology". In *Arts Libéraux et Philosophie au Moyen Âge.* (Actes du Quatrième Congrès International de Philosophie Médiévale.) Montreal: Institut d'Etudes Médiévales, and Paris: J. Vrin, 1969.

Describes discussions of the continuum and the infinite, of the quantification of motion, and of latitudes and the perfection of species, with an appendix on Swineshead's treatise *de loco elementi* as published in the article of Hoskin and Molland, item 1818. The same volume also contains Pearl Kibre, "The it Quadrivium in the Thirteenth Century Universities (with special reference to Paris)", pp. 175–191, and Jean Gagné, "Du Quadrivium aux *scientiae mediae*", pp. 975–986, as well as other studies of the quadrivium.

1839. Murdoch, John. "The Medieval Euclid: Salient Aspects of the Translations of the *Elements* by Adelard of Bath and Campanus of Novara". *Revue de Synthèse* 89 (1968), 67–94.

Argues that the additions and changes to the text appearing in these translations are generally of a didactic nature, attempting to clarify the text, to simplify comprehension, and to make the logical structure of the whole clear.

1840. Murdoch, John. "The Medieval Language of Proportions". In *Scientific Change.* Edited by A. C. Crombie. London: Heinemann, and New York: Basic Books, 1963, 237–271, and discussion, 334–343.

Emphasizes the consequences of the medieval misunderstanding of Eudoxos's definition of the sameness of ratios.

1841. Murdoch, John. "Naissance et développement de l'atomisme au bas Moyen Âge Latin". In *La science de la nature: théories et pratiques.* (Cahiers d'Etudes Médiévales, Vol. 2.) Edited by G.-H. Allard, and J. Ménard. Montreal: Bellarmin, 1974, 11–32.

Survey of medieval mathematical indivisibilism, especially in the work of Henry of Harclay, Walter Chatton, Gerard of Odo, and Nicolas Bonettus.

1842. Murdoch, John. *"Rationes Mathematice": Un aspect du rapport des mathématiques et de la philosophie au Moyen Âge.* (Les Conférences du Palais de la Découverte.) Paris: Université de Paris, 1961.

Studies the application of mathematics in astrological prediction, in the question of the eternity of the world, and with regard to the composition of the continuum.

1843. Murdoch, John. "Superposition, Congruence and Continuity in the Middle Ages". In *Mélanges Alexandre Koyré.* Vol. 1. Paris: Hermann, 1964, 416–441.

Leads up to Thomas Bradwardine's use of superposition in his *Tractatus de continuo.*

1844. North, John D. "Kinematics—More Ethereal than Elementary". In *Machaut's World: Science and Art in the Fourteenth Century.* Edited by Madeleine Pelner Cosman, and Bruce Chandler. (Annals of the New York Academy of Sciences, Vol. 314.) New York: The New York Academy of Sciences, 1978, 89–102.

Compares the techniques used in medieval terrestrial and celestial kinematics.

1845. Pedersen, Olaf. "The Corpus Astronomicum and the Traditions of Medieval Latin Astronomy". *Colloquia Copernicana.* Vol. 3. Warsaw: Zaklad Narodowy Imenia Ossolińskich, 1975, 57–96.

Detailed analysis of the development of the *corpus astronomicum.*

1846. Rose, Paul Lawrence. *The Italian Renaissance of Mathematics: Studies on Humanists and Mathematicians from Petrarch to Galileo.* Geneva: Droz, 1975, 316 pp.

Traces the collaboration of scientists and humanists in bringing about a revival of Greek mathematics in fifteenth- and sixteenth-century Italy. Little internal analysis of the mathematics involved. See also item 1923.

1847. Sesiano, Jacques. "The Appearance of Negative Solutions in Medieval Mathematics". *Archive for History of Exact Sciences* 32 (1985), no. 2, 105–150.

Discusses medieval systems of linear equations and problems that are closely connected with the appearance of negative solutions. Works considered include those by Fibonacci, Nicolas Chuquet, and Luca Pacioli.

1848. Shelby, Lon R. "The Geometrical Knowledge of Medieval Master Masons". *Speculum* 47 (1972), 395–421.

Well-documented discussion of the problem of the use of geometry by cathedral builders.

1849. Simi, Annalisa. “Some 14th and 15th Century Texts on Practical Geometry”. In M. Folkerts, and J. P. Hogendijk, eds. *Vestigia Mathematica*. Amsterdam: Rodopi, 1993, 454-470.

1850. Skabelund, Donald, and Phillip Thomas. “Walter of Odington’s Mathematical Treatment of Primary Qualities”. *Isis* 60 (1969), 331–350.

Use of a relationship like Bradwardine’s in an alchemical work.

1851. Stamm, Edward. “Tractatus de continuo von Thomas Bradwardina”. *Isis* 26 (1936), 13–32.

Surveys the treatise. Superseded by the edition in the dissertation by John Murdoch, item 1868.

1852. Sylla, Edith. “Compounding Ratios: Bradwardine, Oresme, and the first Edition of Newton’s *Principia*”. In *Transformation and Traditioin in the Sciences. Essays Presented to I. Bernard Cohen.* Edited by Everett Mendelsohn. Cambridge: Cambridge University Press, 1984, pg 11-43.

Argues that the “old-fashioned” concept of the compounding of ratios common to Bradwardine, Oresme, and Newton was not false, misguided, or inconsistent, but rather was a mathematically viable alternative to the concept of the compounding of ratios that prevailed after 1700.

1853. Sylla, Edith. “Medieval Concepts of the Latitude of Forms. The Oxford Calculators”. *Archives d’Histoire Doctrinale et Littérarie du Moyen Âge* 40 (1973), 223–283.

Considers the use of latitudes to express functions (pp. 264–270).

1854. Sylla, Edith. “Thomas Bradwardine’s “De continuo” and the Structure of 14th-century Learning”. In *Texts and Contexts in Ancient and Medieval Learning.* Edited by Edith Sylla, and Michael McVaugh. Leiden: Brill, 1997, 148-86.

Uses Thomas Bradwardine’s *De continuo* as a source of evidence about the structure of 14th century learning, particularly as it involved the relations between natural philosophy, mathematics, logic, and theology.

1855. Sylla, Edith. “William Heytesbury on the Sophism ‘Infinita sunt finita’”. *Miscellanea Mediaevalia*, Band 13 (2). (Sprache und Erkenntnis im Mittelalter.) Berlin and New York: Walter de Gruyter, 1981, 628–636.

Describes the medieval application of logical analysis to problems of the infinite.

1856. Tannery, Paul. *Mémoires scientifiques.* Vol. 5. *Sciences exactes au Moyen Âge.* Toulouse: Edouard Privat, 1922.

Contains numerous articles on medieval mathematics, some superseded, others not, for instance, "La géométrie au XI[e] siècle", pp. 79–102.

1857. Thomson, R. B. "Jordanus de Nemore: Opera". *Mediaeval Studies* 38 (1976), 97–144.

Attempts to distinguish works genuinely belonging to Jordanus.

1858. Ullman, B. L. "Geometry in the Mediaeval Quadrivium". In *Studi di bibliografia e di storia in onore di Tammaro de Marinis.* Band 4. Verona: Stamperia Valdonega, 1964, 263–285.

Argues that in the early medieval period works on surveying were used as a source for geometrical material to be used in teaching the quadrivium. There is sufficient information in early manuscripts and library catalogues to trace the history of gromatic collections. Corbie appears to have been a center for geometrical teaching.

1859. Van Wijk, W. E. *Origine et développement de la computistique médiévale.* (Les Conférences du Palais de la Découverte, no. 29.) Paris: Université de Paris, 1954.

Describes medieval computus treatises, which taught the elementary astronomical calculations needed to determine the date of Easter.

1860. Weisheipl, James A., ed. *Albertus Magnus and the Sciences. Commemorative Essays 1980.* Toronto: Pontifical Institute of Mediaeval Studies, 1980.

Includes A. G. Molland, "Mathematics in the Thought of Albertus Magnus", pp. 462–478, and Paul M. J. E. Tummers, "The Commentary of Albert on Euclid's Elements of Geometry", pp. 479–499.

1861. Wieleitner, H. "Zur Geschichte der unendlichen Reihen im christlichen Mittelalter", *Bibliotheca Mathematica*, Series 3, 14 (1914), 150–168.

Infinite series in the work of Oresme, Alvarus Thomas, et al.

1862. Wilson, Curtis. *William Heytesbury. Medieval Logic and the Rise of Mathematical Physics.* Madison: University of Wisconsin Press, 1956; 2nd printing 1960.

Description of Heytesbury's studies of temporal limits, maxima and minima, and measures of motions, with comparisons to related works. No texts. Although Heytesbury in effect sums infinite series and the like, his major techniques rely on logical distinctions more often than on mathematical calculations.

1863. Zoubov, V. P. "Traktat Bradvardina O Kontinuume". *Istoriko-Matematicheskie Issledovaniia* 13 (1960), 385–440.

Contains the Latin of the major enunciations of the treatise; now superseded by the dissertation of John Murdoch, item 1868.

1864. Zoubov, V. P. "Walter Catton, Gérard d'Odon, et Nicolas Bonet". *Physis* 1 (1959), 261–278.

Describes fourteenth-century disputes over the composition of continua.

Dissertations (Unpublished Unless Otherwise Noted)

1865. Brown, Joseph E. "The *Scientia de Ponderibus* in the Later Middle Ages". University of Wisconsin, 1967.

1866. Cunningham, T. J. "Book V of Euclid's *Elements* in the Twelfth Century: The Arabic-Latin Traditions". University of Wisconsin, 1972.

1867. Goldat, G. D. "The Early Medieval Traditions of Euclid's *Elements*". University of Wisconsin, 1957.

1868. Murdoch, John. "Geometry and the Continuum in the Fourteenth Century: A Philosophical Analysis of Thomas Bradwardine's Tractatus de continuo". University of Wisconsin, 1957.

1869. Schrader, Sister Walter Reginald, O. P. "The Epistola de proportione et proportionalitate of Ametus filius Josephi". University of Wisconsin, 1961.

1870. Van Ryzin, Sister Mary St. Martin. "The Arabic-Latin Tradition of Euclid's *Elements* in the Twelfth Century". University of Wisconsin, 1960.

RENAISSANCE MATHEMATICS

It is not possible to draw a strict chronological division between the Middle Ages and the Renaissance. In general historical studies the Renaissance is seen as a cultural or stylistic movement marked by the rise of modern statecraft, humanism, realistic art and other features, which began to appear in Italy in the fourteenth century and gradually spread to encompass all of Europe by the end of the sixteenth century. In mathematics it is possible to find a similar pattern only by drawing a topical or sociological distinction between what might loosely be called "scholastic" and "vulgar" mathematics. Thus "medieval mathematics" can be identified with the mathematics studied by the scholastics of the medieval universities. It was conducted primarily in the Latin language and included such topics as algorism, arithmetic (number theory), Euclidean geometry, proportion theory, optics, and several related fields. It also tended to be more theoretical than practical in that it was seldom used to solve practical problems. "Vulgar" mathematics, in contrast, was driven primarily by the need to solve problems of calculation and measurement in business and construction. It was conducted primarily in the vernacular languages of Europe by merchants, bankers, masons, artists, architects, and engineers who generally did not have a university education. It is this "vulgar mathematics" that can be loosely equated with "Renaissance mathematics."

Adopting this definition, however, forces us to place the beginning of Renaissance mathematics in 1202 with the appearance of Leonardo Pisano's *Liber abbaci*, an encyclopedic compendium of mathematics as it was then practiced in the Arab world. By the fourteenth century this founding text had led to the formation of a well-defined "abbacus" tradition in the Italian city states comprising schools, teachers, and books devoted to the promulgation and practice of practical mathematics. In the fifteenth and sixteenth centuries this style of mathematics spread northwards into the countries of Germany, France, and England and became the characteristic style of European mathematics.

Simultaneously, some of the better known aspects of Renaissance culture, such as humanism and art, also contributed to mathematics, leading for example to the recovery of the primary texts of classical mathematics and the development of the theory of perspective. The sixteenth century also saw the growth of modern mechanics, optics, and trigonometry, while logarithms appeared soon after the century's end. However, the most important contribution of the Renaissance to mathematics was the development of algebra. Originally an Arab art of problem solving included in Leonardo's book, it was taken into the abbacus tradition where it acquired new forms and methods. In the sixteenth century this merged with humanist mathematics to form the modern theory of equations and lay the foundation for analytic geometry, analysis, and the eventual development of the calculus.

General Histories and Studies

General Histories of Mathematics

The general histories of mathematics do not reflect the latest research and generally cover only the better-known figures whose works were printed, that is, which appeared after 1470. The best surveys remain two century-old German works.

1871. Cantor, Moritz B. *Vorlesungen über Geschichte der Mathematik*. Vol. II. *Von 1200–1668*. 2nd ed. Leipzig: Teubner, 1900. Reprinted New York: Johnson Reprint Corporation, 1965.

This volume contains extensive studies of Renaissance algebraists from Leonardo da Pisa to Viète on pp. 1–648. See item 891.

1872. Zeuthen, H.-G. *Geschichte der Mathematik im 16. und 17. Jahrhundert*. Leipzig: Teubner, 1903. Reprinted New York: Johnson Reprint Corporation, 1966, viii + 434 pp.

This is still the best general introduction, although it only covers the late Renaissance. See item 2074.

1873. Boyer, Carl B. *A History of Mathematics*. New York: John Wiley, 1968.

Useful only as a general survey of the major fifteenth- and sixteenth-century figures and developments. Chapter XV, "The Renaissance" (pp. 297–332), covers major developments in all fields up to 1575. The beginning of Chapter XVI, "Prelude to Modern Mathematics," covers Viète. See item 887.

1874. Kline, Morris. *Mathematical Thought from Ancient to Modern Times*. New York: Oxford University Press, 1972.

Useful only as a general survey of the major fifteenth- and sixteenth-century figures and developments. The "Mathematical Contributions in the Renaissance" covered in chapter 12 (pp. 231–249) should be supplemented by the survey of Viète in chapter 13. See item 902.

1875. Loria, Gino. *Storia delle matematiche dall'alba della civilità al secolo XIX*. 2nd ed. Milan: Hoepli, 1950, 975 pp.

Chapters 12 (pp. 219–238) and 15–17 (pp. 287–352) give a general survey of arithmetic and algebra from Leonardo to Viète, with biographical sketches of the leading mathematicians. There is a short bibliography at the end of each chapter.

1876. Smith, David Eugene. *History of Mathematics*. Boston: Ginn & Co., 1923–25. 2 vols. Reprinted New York: Dover, 1958.

The chronological survey in Vol. I includes capsule descriptions of the most important figures and works from Leonardo to Viète. The topical surveys in Vol. II include material from many Renaissance texts. See item 905.

General Histories of Science

General histories of science are limited in their approach to Renaissance mathematics.

1877. Koyré, Alexandre. "Les mathématiques". In René Taton, ed. *Histoire générale des sciences.* Tome II. *La science moderne (de 1450 à 1800).* Paris: Presses Universitaires de France, 1958, 12–51. English translation London: Thames and Hudson, 1964.

This is the most thorough treatment. It discusses Nicholas of Cusa, Peurbach, Regiomontanus, the first printed arithmetics, and the development of algebra in Germany, France, Italy, and the Low Countries.

Histories of Science in the Renaissance

Boas and Wightman (see following items), the two major historians of Renaissance science, also limit their attention to the sixteenth century.

1878. Boas, M. *The Scientific Renaissance, 1450–1630.* New York: Harper and Brothers, 1962.

Chapter 7 (pp. 197–237) treats primarily navigation, cartography, and mechanics.

1879. Wightman, W. P. D. *Science and the Renaissance. An Introduction to the Study of the Emergence of the Sciences in the Sixteenth Century.* Edinburgh: Oliver and Boyd, 1962.

Chapter VI, "The Mathematical Disciplines" (pp. 87–99), treats arithmetic, algebra, trigonometry, and geometry; Chapter VIII, "Mathematical Practitioners" (pp. 129–147), covers navigation and cartography.

1880. Wightman, W. P. D. *Science in a Renaissance Society.* London: Hutchinson University Library, 1972.

Chapter 3 (pp. 42–56) treats Italian mathematics and the art of the high Renaissance, Chapter 10 (pp. 130–140) covers the Northern Renaissance of the sixteenth century.

Bibliographies

1881. May, Kenneth O. *Bibliography and Research Manual of the History of Mathematics.* Toronto: University of Toronto Press, 1973.

This comprehensive bibliography lists most of the works published prior to about 1970. Works on Renaissance mathematics can be found under various headings, including: Algebra (pp. 393–395), Arithmetic (pp. 402–406), Cubic equations (pp. 422–423), False position (p. 437), Quadratic equations (pp. 488–489), Quartic equations (pp. 489–490), XIIIth to XVIth centuries (pp. 640–643), Italy, (pp. 659–661), Bologna (p. 671), and the names of individual mathematicians. See also items 14 and 1018.

1882. Barbieri, Francesco, and Luigi Pepe. "Bibliografia italiana di Storia delle Matematiche 1961-1990". *Bollettino di storia delle scienze matematiche* 12 no. 1 (1992), 3–181.

A valuable supplement to May (item 1881), but unfortunately only for works published in Italian.

1883. Simonetti, Carla. "Catalogo degli scritti di Gino Arrighi sulla storia della scienza". In *Contributi alla storia delle matematiche. Scritti in onore di Gino Arrighi.* (Accademia Nazionale di Scienze, Lettere e Arti. Collana di Studi n. 8.) Modena: Muchi, 1992, 95–165.

Gino Arrighi has been the most prolific writer on Renaissance mathematics, describing and transcribing dozens of manuscript texts and publishing notices on numerous Renaissance mathematicians. This bibliography lists 303 articles and books on the history of science that appeared between between 1930 and 1989, many of which deal with Renaissance mathematicians and mathematics texts. On pp. 19–28 Raffaella Franci lists the codices he has transcribed and published. An additional 28 articles on the history of mathematics published from 1990-1995 are listed on pp. 422–425 in *Itinera Mathematica. Studi in onore di Gino Arrighi per il suo* 90° *compleanno*, Siena: Università di Siena, 1996.

1884. Rome, A. "Le R. P. Henri Bosmans, S. J. (1852–1928): notice biographique et index analytique de ses travaux historiques". *Isis* 12 (1929), 88–112.

Bosmans wrote many articles on important sixteenth- century mathematicians, including Gemma Frisius, Guillaume Gosselin, Pedro Nuñez, Jacques Peletier, Adriaen van Roomen, and Simon Stevin. These and others are listed on pp. 94–100.

Topical Studies

Arithmetic and Algebra

Arithmetic and algebra during the Renaissance developed in distinctly national schools. For more information see the section on National Studies, particularly for Italy, France, and Germany, as well as the entries listed for relevant individual mathematicians. The following works focus on themes or issues common to many national traditions.

1885. Van Egmond, Warren. “Abbacus Arithmetic”. In I. Grattan-Guinness, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. I. London: Routledge, 1994, 200–209.

This short article outlines the major characteristics of Italian arithmetic and algebra as the basis for general European mathematics.

1886. Reich, Karin. “The ’Coss’ Tradition in algebra”. In I. Grattan-Guinness, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. I. London: Routledge, 1994, 192–199.

This companion article summarizes the major developments in algebra in Italy, France, and Germany from Leonardo of Pisa to Viète.

1887. van der Waerden, B. L. *A History of Algebra from al-Khwarizmi to Emmy Noether*. Berlin: Springer-Verlag, 1985, xii + 271 pp.

Pp. 32–69 summarize the major developments in algebra from 1200 to 1600, including a number of the Italian abbacists not cited in other book-length works.

1888. Gericke, Helmuth. *Mathematik im Abendland. Von den römischen Feldmessern bis zu Descartes*. Berlin: Springer-Verlag, 1990. xiv + 352 pp.

Pp. 209–269 summarize the major developments in algebra from 1450 to 1600.

1889. Kloyda, Mary Thomas à Kempis. “Linear and Quadratic Equations: 1550-1660”. Ann Arbor: Edwards Brothers, 1935.

This is still the most thorough and technical survey of the subject for this period. A brief summary and list of the texts consulted was published in *Osiris* 3 (1938), 165–192.

1890. Russo, François. “La constitution de l’algèbre au XVI^e^ siècle: étude de la structure d’une évolution”. *Revue d’histoire des sciences* 12 (1959), 193–208.

A brief survey that focuses on the development of algebraic notations, symbols, and methods.

1891. Swetz, Frank. “Fifteenth and Sixteenth Century Arithmetic Texts: What Can We Learn from Them?” *Science & Education* 1 no. 4 (1992), 365–378.

An elementary survey of the types of problems found in Renaissance arithmetic texts and their influence.

1892. Cajori, Florian. *A History of Mathematical Notations*. Vol I. *Notations in Elementary Mathematics*. Chicago: Open Court, 1928. Reprinted 1974.

Pp. 89–187 describe the symbols used by Renaissance authors from Leonardo to Viète. Pp. 229–400 contain a topical survey of symbols and methods, with examples from Renaissance texts scattered throughout. See also item 890.

1893. Tropfke, Johannes. *Geschichte der Elementarmathematik*. 4. Auflage. Band 1. *Arithmetik und Algebra*. Edited by Kurt Vogel, Karin Reich, and Helmuth Gericke. Berlin: Walter de Gruyter, 1980, xiv + 742 pp.

This "4th edition" is actually a completely new book, although following the original Tropfke in making a longitudinal survey of mathematics by topics, methods, and problems across all periods and cultures. Examples from many Renaissance mathematics texts are included throughout the book. The massive bibliography and indexes make this edition far more useful than the original, which was published in three editions of multiple volumes from 1902 to 1937 as *Geschichte der Elementar-Mathematik in systematischer Darstellung mit besonderer Berücksichtigung der Fachwörter*. These can, however, still be gleaned for useful information. See also items 1669, 2464.

1894. Williams, Jack. "Mathematics and the Alloying of Coinage 1202-1700". *Annals of Science* 52 (1995), 213–263.

A thorough survey of the mathematics and practice of alligation from Leonardo through the seventeenth century, drawn from Italian and English sources. Its detail makes it the fundamental source for this subject.

1895. Allen, Michael T. *Nuptial Arithmetic: Marsilio Ficino's Commentary on the Fatal Number in Book VIII of Plato's Republic*. Berkeley: University of California Press, 1994.

The Latin text and translation of three texts illustrating Ficino's mathematical philosophy with a detailed commentary and analysis. This is not an entry-level work but a careful scholarly study of the kind of mathematical philosophy common in the Renaissance. Contains a detailed bibliography.

Probability

1896. Schneider, Ivo. "The Market Place and Games of Chance in the Fifteenth and Sixteenth Centuries". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600*. Oxford: Clarendon Press, 1988, 220–235.

The author has argued that the origins of probability lie in the commercial, risk-taking, and gaming activities of Italian merchants. In this article he examines how the problem of points, which drew examples from jurisprudence and economics, contributed to this development. The notes adequately survey the earlier literature on this issue.

1897. Ineichen, Robert. “Dante-Kommentare und die Vorgeschichte der Stochastik”. *Historia Mathematica* 15 (1988), 264–269.

The author shows how the “gioco della zara” found in early Dante commentaries, particularly that of Jacopo Giovanni della Lana, contains elementary ideas of stochastics.

1898. Takacs, Lajos. “The Problem of Points”. *The Mathematical Scientist* 19 no. 2 (1994), 119–139.

The author follows the historical development of the problem from its first publication by Pacioli to its later development in the seventeenth century.

Geometry

1899. L’Huillier, Hervé. “Practical Geometry in the Middle Ages and the Renaissance”. In I. Grattan-Guinness, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* Vol. I. London: Routledge, 1994, 192–199.

This short article gives a concise survey of the main features of the tradition.

1900. Gericke, Helmuth. *Mathematik im Abendland. Von den römischen Feldmessern bis zu Descartes.* Berlin: Springer-Verlag, 1990, xiv + 352 pp.

Pp. 164–209 provide a good survey of the development of practical geometry and its related fields in the Renaissance.

1901. Schneider, Ivo. “Die mathematischen Praktiker im See-, Vermessungs-, und Wehrwesen vom 15. bis zum 19. Jahrhundert”. *Technikgeschichte* 37 (1970), 210–242.

Looks at the development of instruments used in artillery, fortifications, surveying, and navigation over four centuries, but focused on sixteenth-century Germany.

1902. Folkerts, Menso. “Die Entwicklung und Bedeutung der Visierkunst als Beispiel der praktischen Mathematik der frühen Neuzeit”. *Humanismus und Technik* 18 (1974), 1–41.

This is the most complete study of the development of wine gauging in Germany, looking at its mathematical, practical, and social aspects. It is drawn entirely from original documents and contains a list of manuscripts and texts consulted.

1903. Meskens, Ad. “Wine Gauging in Late 16th- and Early 17th-Century Antwerp”. *Historia Mathematica* 21 no. 2 (1994), 121–147.

A detailed study of the activities and mathematical practices of wine gaugers in one of the largest commercial cities of the period.

1904. Simi, Annalisa. "Celerimensura e strumenti in manoscritti dei secoli XIII-XV". In *Itinera Mathematica. Studi in onore di Gino Arrighi per il suo 90° compleanno*. Edited by Raffaella Franci, Paolo Pagli, and Laura Toti Rigatelli. Siena: Università di Siena, 1996, 71–121.

Studies geometrical problems involving optical sighting devices as they appear in Italian manuscripts from Leonardo to Calandri.

1905. Homann, Frederick A. "Christopher Clavius and the Renaissance of Euclidean geometry". *Archivum Historicum Societatis Iesu* 52 (1983), 233–246.

A comparison of three roughly contemporary works on Euclid by Dee, Clavius, and Commandino and their influence on subsequent Euclid studies.

Trigonometry

1906. Bond, John D. "The Development of Trigonometric Methods down to the Close of the XVth Century". *Isis* 4 (1921), 295–323.

Despite their age, this and the following work still provide the only adequate survey of the history of trigonometry in English.

1907. Zeller, M. C. *The Development of Trigonometry from Regiomontanus to Pitiscus*. Dissertation, University of Michigan, 1944. Reprinted Ann Arbor: Edwards Brothers, 1946.

1908. Thoren, Victor E. "Prosthaphaeresis Revisited". *Historia Mathematica* 15 no. 1 (1988), 32–39.

Traces the discovery of the trigonometric product formulas in the works of Johannes Werner, Joost Bürgi, and Paul Wittich, which were first published by Ursus in 1588.

1909. Miura, Nobuo. "The Applications of Trigonometry in Pitiscus: A Preliminary Essay". *Historia Scientiarum. International Journal of the History of Science Society of Japan* no. 30 (1986), 63–78.

Surveys the trigonometric work of Pitiscus and gives a general view of the development of trigonometry from Regiomontanus.

Mechanics

1910. Drake, S., and I. E. Drabkin. *Mechanics in Sixteenth-Century Italy.* Madison: University of Wisconsin Press, 1968, 428 pp.

This work is fundamental for the study of mechanics in the Renaissance. It contains translations from Tartaglia, Benedetti, Guidobaldo, and Galileo, plus a historical survey of the tradition that discusses several other sixteenth-century figures.

1911. Knobloch, Eberhard. "Mariano di Jacopo detto Taccolas *De machinis*. Ein Werk der italienischen Frührenaissance". *Technikgeschichte* 48 (1981), no. 1, 1–27.

In addition to giving a detailed description and analysis of Taccola's work, this article examines its historical background and influence on Francesco di Giorgio Martini and Leonardo da Vinci, and also provides a review of the earlier literature on fifteenth-century engineering manuscripts.

1912. Laird, W. R. "The Scope of Renaissance Mechanics". *Osiris* 2, Second Series (1986), 43–68.

Studies the changing perceptions of the mechanical tradition in the course of the sixteenth-century reaction to the publication of Pseudo-Aristotle's *Mechanical Problems* by examining the life and works of several commentators.

1913. Laird, W. R. "Archimedes among the Humanists". *Isis* 82 (1991), no. 314, 629–638.

Surveys the study of Archimedes from the Middle Ages to Galileo, and finds the cause of the Archimedean revival of the Renaissance in the humanists' interest in the practical usefulness of his machines.

1914. Bertoloni Meli, Domenico. "Guidobaldo dal Monte and the Archimedean revival". *Nuncius. Annali di Storia della Scienza* 7 no. 1 (1992), 3–34.

A historical survey of mathematics in Italy in the second half of the sixteenth century, focused on Guidobaldo but also including Benedetti and Commandino.

Art and Architecture

1915. Edgerton, Samuel Y., Jr. *The Renaissance Rediscovery of Linear Perspective.* New York: Basic Books, 1975, 223 pp.

In the massive literature on Renaissance art and architecture, historians of mathematics can safely focus on the relatively narrow issue of the development of the theory and practice of mathematical perspective. Edgerton's detailed and comprehensive study provides the foundation for all such research.

1916. Edgerton, Samuel Y., Jr. *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution.* Ithaca: Cornell University Press, 1991, xii + 319 pp.

A more philosophical discussion of the geometrization of Western art and science, with a comparative look at Chinese art and science. The book draws many examples from Renaissance scientific and technical books.

1917. Field, J. V. *The Invention of Infinity: Mathematics and Art in the Renaissance.* Oxford: Oxford University Press, 1997, xii + 250 pp.

The most recent survey of the question; it follows the development from Giotto and scholastic theory through the eighteenth century, although the focus is clearly on the Renaissance. There are two chapters on Piero della Francesca's mathematics.

1918. Field, J. V. "Perspective and the Mathematicians: Alberti to Desargues". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600.* Oxford: Clarendon Press, 1988, 236–263.

Notes the increasing sophistication of mathematical perspective and its greater use in architecture from Alberti to Barozzi.

1919. Wittkower, Rudolf. *Architectural Principles in the Age of Humanism.* 3rd ed. London: Alec Tiranti, 1962. 4th ed. London: Academy Editions; New York: St. Martin'sPress, 1988.

The fundamental study of how the theory of proportion was used in Renaissance architecture, focused primarily on the work of Alberti and Palladio, but following through to the decline of proportion theory in the eighteenth century.

1920. Frangenberg, Thomas. "The Image and the Moving Eye. Jean Pélerin (Viator) to Guidobaldo del Monte". *Journal of the Warburg and Courtauld Institutes* 49 (1986), 150–171.

A study of how the optical tradition of Alhazen merged into the perspective tradition of Alberti in the work of Pélerin, Barbaro, Barozzi, Danti, Guidobaldo, Leonardo, and Commandino.

National Studies

Italy

1921. Van Egmond, Warren. "The Contributions of the Italian Renaissance to European Mathematics." In *Symposia mathematica.* Vol. XXVII. London/New York: Academic Press, 1986, 51–67.

The author maintains that the mathematicians of the Italian Renaissance were primarily responsible for developing the methods of numeration and calculation used in Western culture, developing the modern methods of algebra, and recovering the texts of classical mathematics, as well as developing modern mechanics and the theory of perspective.

1922. Van Egmond, Warren. *Practical Mathematics in the Italian Renaissance: A Catalog of Italian Abbacus Manuscripts and Printed Books to 1600.*

(Annali dell' Istituto e Museo di Storia della Scienza, Monografia N. 4.) Firenze: Istituto e Museo di Storia della Scienza, 1980, xliv + 442 pp.

Contains detailed descriptions of more than 400 manuscripts and books, with a historical introduction and extensive indexes. The same author's dissertation, *The Commercial Revolution and the Beginnings of Western Mathematics in Renaissance Florence, 1300–1550*, University of Indiana, 1976, 628 pp., contains a longer discussion, more detailed descriptions of the manuscripts, and bio-bibliographical summaries of all known Italian abbacists.

1923. Rose, Paul Lawrence. *The Italian Renaissance of Mathematics: Studies on Humanists and Mathematicians from Petrarch to Galileo*. Geneva: Droz, 1975, 316 pp.

This is an extensive and well documented study of the humanist tradition in Renaissance mathematics, with chapters on Regiomontanus, Tartaglia, Benedetti, Maurolico, and the Urbino school. Its detailed notes make it the fundamental work on humanist mathematics. See also item 1846.

1924. Franci, Raffaella, and Laura Toti Rigatelli. "Towards a History of Algebra from Leonardo of Pisa to Luca Pacioli". *Janus* 72 (1985), 17–82.

This is the best short survey of what is known about the development of algebra in Italy before 1500. It is largely drawn from recent studies of manuscript sources and thus contains information not found in most of the standard surveys. It also includes a review of the previous literature and a comprehensive bibliography.

1925. Toti Rigatelli, Laura. "L'algebra in Italia nel Tre-Quattrocento". In *Contributi alla storia delle matematiche. Scritti in onore di Gino Arrighi*. (Accademia Nazionale di Scienze, Lettere e Arti. Collanadi Studi n. 8.) Modena: Muchi, 1992, 41–52.

The author and her colleagues at the University of Siena have been the most active in publishing and describing the manuscript texts of Renaissance Italian mathematics. The publication series *Quaderni del Centro Studi della Matematica Medioevale* should be consulted for available texts. This brief description of 20 manuscripts is best used a guide to the publications in that series.

1926. Franci, Raffaella, and Laura Toti Rigatelli. "Fourteenth-century Italian Algebra". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600*. Oxford: Clarendon Press, 1988, 11–29.

Provides a brief survey of known fourteenth-century manuscripts and their algebraic contents.

1927. Van Egmond, Warren. "The Algebra of Master Dardi of Pisa". *Historia Mathematica* 10 no. no. 4 (1983), 399–421.

A description and mathematical summary of the earliest text to correctly solve a cubic equation.

1928. Franci, Raffaella. "Antonio de' Mazzinghi: An Algebraist of the 14th Century". *Historia Mathematica* 15 (1988), 240–249.

Gives a brief description of his life and a mathematical analysis of his works, showing he was one of the most skilled algebraists of his time.

1929. Franci, Raffaella. "Le matematiche dell'abaco del quattrocento". In *Contributi alla storia delle matematiche. Scritti in onore di Gino Arrighi*. (Accademia Nazionale di Scienze, Lettere e Arti. Collana di Studi n. 8.) Modena: Muchi, 1992, 53–74.

A general description of the tradition and texts, and their relation to teaching methods and art.

1930. Swetz, Frank J. *Capitalism and Arithmetic. The New Math of the 15th Century. Including the full text of the Treviso Arithmetic of 1478.Translated by David Eugene Smith.* La Salle, IL: Open Court Publishing Co., 1987, xx + 345 pp.

A translation of the first printed Italian arithmetic, with a commentary and historical background that serves as a good introduction to the material.

1931. Bortolotti, Ettore *Storia della matematica nella Università di Bologna.* Bologna: N. Zanichelli, 1947, 226 pp.

Gives a complete history of the teaching of mathematics and astronomy at the university from its founding to the nineteenth century. Pages 1–80 follow developments through Bombelli.

1932. Speziali, P. "L'école algébriste italienne du XVI^{e} siècle et la résolution des équations des 3e et 4e degrés". In *Sciences de la Renaissance.* VIII^{e} *Congrès International de Tours.* Paris: J. Vrin, 1973, 107–120.

Surveys the study of mathematics in the Italian universities from Scipione del Ferro to Bombelli.

1933. Biagioli, Mario. "The Social Status of Italian Mathematicians, 1450–1600". *History of Science* 27 no. 75, part 1 (1989), 41–95.

Notes the social gap between abbacist-engineers and astrologer-physicians. Draws particularly on the example of Urbino. Contains a 570-item bibliography.

1934. Gatto, Romano. *Tra scienza e immaginazione: Le matematiche presso il collegio gesuitico napoletano (1552-1670 ca).* Firenze: Olschki, 1994, 392 pp.

A detailed history of the school, rich in historical context.

1935. Libri, Guillaume. *Histoire des sciences mathématiques en Italie, depuis la renaissance des lettres jusqu' à la fin du dix-septième siècle.* Paris: Jules Renouard, 1838–1841. 4 vols. Reprinted New York: Johnson Reprint, 1966. 2nd ed. Halle: Schmidt, 1865.

Libri's work laid the foundation for the modern study of the history of mathematics in Italy. It can still be consulted with profit, particularly for the texts contained in its appendices. Vols. II and III deal with the Renaissance.

France

1936. Van Egmond, Warren. "How Algebra Came to France". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600.* Oxford: Clarendon Press, 1988, 127–144.

Provides a concise survey of the many phases algebra and mathematics went through in France from the introduction of the first Arabic algebras to Viète.

1937. Sesiano, Jacques. "Une arithmétique médiévale en langue provençale". *Centaurus* 27 no. 1 (1984), 26–75.

Describes and paraphrases the earliest mathematical manuscript in French.

1938. Cassinet, Jean. "Le manuscrit XXVI de Cesena: important maillon occitan de transmission de l'algorisme au 15ème siècle". *Bollettino di Storia delle Scienze Matematiche* 13 no. 2 (1993), 251–285.

A detailed study of one of the most important French manuscripts, including mathematical analyses, historical context, and a comparison with other manuscripts.

1939. Margolin, Jean-Claude. "L'enseignement des mathématiques en France (1540-70): Charles de Bovelles, Fine, Peletier, Ramus". In Peter Scharratt, ed. *French Renaissance Studies, 1540-70. Humanism and the Encyclopedia.* Edinburgh: University Press, 1976, 109–155.

An excellent introduction to the mathematics of the period.

1940. Davis, Natalie Z. "Mathematicians in the Sixteenth-Century French Academies: Some Further Evidence". *Renaissance News* 11 (1958), 3–10.

Studies three French mathematicians known to have been teaching in the French academies at the end of the century: Miles de Norry, Jacques Chauvet, and Guillaume Gosselin.

1941. Benoit, Paul. "Arithmétiques commerciales et comptabilités dans la France médievale". In Paul Benoit, Karine Chemla, and Jim Ritter, eds. *Histoire de fractions, fractions d'histoire*. Basel: Birkhäuser, 1992, 307–323.

A study of the use of fractions in French merchant account books and arithmetic manuals.

1942. Cifoletti, Giovanna C. "La question de l'algèbre: Mathématiques et rhétorique des hommes de droit dans la France du 16e siècle". *Annales HSS* 6 (1995), 1385–1416.

A study of the French humanist tradition of algebra before Viète.

Germany

1943. Kaunzner, Wolfgang. "Über das Eindringen algebraischer Kenntnisse nach Deutschland". In *Rechenpfennige. Aufsätze zur Wissenschaftsgeschichte*. München: Forschungsinstitut des Deutschen Museums, 1968, 91–122.

This short article provides the best review of the development of algebra in Germany before 1500. It cites all of the basic manuscripts and studies and has a good bibliography of studies printed up to its date of publication. However, there have been a considerable number of new texts and studies published since then, the best of which are listed below.

1944. Folkerts, Menso. "Conrad Landvogt, ein bisher unbekannter Algebraiker um 1500". In Sergei S. Demidov, Folkerts Menso, David E. Rowe, and Christoph J. Scriba, eds. *Amphora: Festschrift für Hans Wussing zu seinem 65. Geburtstag*. Basel: Birkhäuser, 1992, 229–259.

Although focused on developments in Erfurt and the life and work of Landvogt, this article provides a good summary of the development of algebra in Germany before 1500.

1945. Grössing, Helmuth. *Humanistische Naturwissenschaft. Zur Geschichte der Wiener mathematischen Schulen des 15. und 16. Jahrhunderts.* (Saecula Spiritalia, 8.) Baden-Baden: Valentin Koerner, 1983, 355 pp.

A good survey of the teaching of mathematics in Vienna from the founding of the university to the middle of the sixteenth century. The author divides it into two main periods/schools: that of John of Gmunden, Peurbach, and Regiomontanus; and that of Celtus, Stabius, Stiborius, and Tannstetter.

1946. Vogel, Kurt. *Die Practica des Algorismus Ratisbonensis.* München: C. H. Beck, 1954, xi + 283 pp., 8 plates.

A composite edition from six manuscripts of the oldest known German arithmetic, with full scholarly apparatus and detailed introduction and studies of the text.

1947. Vogel, Kurt. *Die erste deutsche Algebra aus dem Jahre 1481. Nach eine Handschrift aus C80 Dresdensis.* (Bayerische Akademie der

Wissenschaften. Mathematisch-Naturwissenschaftliche Klasse. Abhandlungen. Neue Folge.) no. 160 (1981), 52 pp., 3 plates.

Provides the text, commentary, and background of the oldest German algebra.

1948. Vogel, Kurt, ed. "Das Bamberger Blockbuch. Inc. typ. Ic I44 der Staatsbibliothek Bamberg". Munich: K. G. Saur, 1980, 105 pp.

Contains a facsimile, transcription, commentary, and appendices of the first printed arithmetic book in the German language.

1949. Wagner, Ulrich. *Das Bamberger Rechenbuch von 1483.* Edited by Eberhard Schröder. Weinheim: VCH, 1988, 311 pp.

A facsimile of the Zwickau copy of the earliest dated German arithmetic, with transcription, notes, and bibliography.

1950. Schröder, Eberhard. *Ein mathematisches Manuskript aus dem 15. Jahrhundert.* (Algorismus, 16.) München: Institut für Geschichte der Naturwissenschaften, 1995, 365 pp.

A description, facsimile, and transcription of an early German arithmetic manuscript, believed to date from around 1460, together with tables comparing it to two contemporary texts.

1951. Kaunzner, Wolfgang. *Über die Handschrift Clm 26639 der Bayerischen Staatsbibliothek Munchen.* (Arbor Scientiarum. Beiträge zur Wissenschaftsgeschichte, Riehe B: Texte, 1.) Hildesheim: Gerstenberg Verlag, 1978, v + 125 pp.

This important manuscript contains the algebra notes apparently used by Widman for his *Behende und hubsche Rechnung* of 1489. The text gives a list of contents and partial transcription.

1952. Kaunzner, Wolfgang. "Über das Zusammenwirken von Systematik und Problematik in der frühen deutschen Algebra". *Sudhoffs Archiv* 54 (1970), 299–315.

A brief survey of the main developments in German algebra, particularly the development of algebraic symbolism, in the period from 1460 to 1550.

1953. Weidauer, Manfred, ed. *Heinrich Schreyber aus Erfurt, genannt Grammateus. Festschrift zum 500. Geburtstag.* (Algorismus, 20.) München: Institut für Geschichte der Naturwissenschaften, 1996, 165 pp.

A collection of eight articles on Schreyber and his time.

Netherlands (Low countries)

1954. Struik, Dirk J. *The Land of Stevin and Huygens. A Sketch of Science and Technology in the Dutch Republic during the Golden Century.* Dordrecht: D. Reidel, 1981, xx + 162 pp., 25 illustrations.

English translation by the author from the revised Dutch edition. Chapters IV and V (pp. 32–60) are devoted to mathematics, navigation, and the work of Simon Stevin.

1955. Smeur, A. J. E. M. *The Sixteenth Century Arithmetics Printed in the Netherlands.* The Hague, 1960, 175 pp.

1956. Snelders, H. A. M. "Science in the Low Countries During the Sixteenth Century. A Survey". *Janus* 70 no. 3-4 (1983), 213–227.

A short list of the principal figures in Netherlands science, including mathematicians. Has a good bibliography.

1957. Bockstaele, P. "Gielis van den Hoecke and His *Wonderful Book on the Noble Art of Arithmetic* of 1537". *Mededelingen van de Koninklijke Academie voor Wetenschappen, Letteren en Schone Kunsten van Belgie. Klasse der Wetenschappen.* 47 no. 1 (1985), 1–29. In Dutch.

A comprehensive article surveying the facts of van den Hoecke's life and the contents of his work, the earliest printed Dutch work on algebra.

1958. Meskens, Ad. "Mathematics Education in Late Sixteenth-century Antwerp". *Annals of Science* 53 (1996), no. 2 137–155.

Gives a picture of the social status of Antwerp arithmetic teachers, their religious convictions and content of their libraries based on records left from the 1585 sack of the city.

England

1959. Taylor, Eva G. R. *The Mathematical Practitioners of Tudor and Stuart England, 1485–1714.* Cambridge: The University Press, 1954, xi + 443 pp., 12 plates.

Chapters I and II (pp. 7–48) provide a thorough survey of all known mathematical activities in England in the sixteenth century, with a strong focus on navigational techniques and instruments. Part II provides biographical summaries of all known practitioners and descriptions of all known works, both printed and manuscript. This book is the foundation for the study of mathematics in Renaissance England. See also item 2107.

1960. Waters, David W. *The Art of Navigation in England in Elizabethan and Early Stuart Times.* London: Hollis and Carter; New Haven: Yale University Press, 1958, xl + 696 pp., 87 plates. 2nd ed. Greenwich: Trustees of the Nautical Maritime Museum, 3 vols. 1978.

A complete history of the development of navigation in England during the Renaissance, giving careful attention to the development of mathematical and astronomical techniques. The second edition merely splits the massive 700 page book into three parts. See also item 3373.

1961. Richeson, A. W. "The First Arithmetic Printed in English". *Isis* 37 (1947), 47–56.

A thorough and detailed study of the "An Introduction for to Lerne to Recken with the Pen, or with Counters" published at St. Albans in 1537.

1962. Johnston, Stephen. "The Identity of the Mathematical Practitioner in 16th-Century England". In Irmgard Hantsche, ed. *Der "mathematicus". Zur Entwicklung und Bedeutung einer neuen Berufsgruppe in der Zeit Gerhard Mercators*. Vol. 4. (Duisburger Mercator-Studien.) Bochum: Brockmeyer, 1996, 93–120.

Spain and Portugal

1963. Rey Pastor, J. *Los matemáticos españoles del siglo XVI*. Madrid, 1934, 164 pp.

A review of the major authors and their works. Still the foundation of modern research on Spanish mathematics.

1964. Karpinski, Louis C. "The First Printed Arithmetic of Spain". *Osiris* 1 (1936), 411–420.

Gives a description and partial transcription of Francesch Sanct Climent's *Suma de la Art de Arismetica*, printed at Barcelona in 1482.

1965. Frick, Bertha M. "The First Portugese Arithmetic". *Scripta Mathematica* 11 (1945), 327–339.

A description of the *Tratado da pratica d'arismetica composta & ordenada per Gaspar Nicolas*, with a discussion of the background of printing in practical mathematics before that time.

1966. Calderon, Calixto P. "The 16th-century Iberian Calculatores". *Revista de la Union Matematica Argentina* 35 (1989), 245–258.

A recent survey of the sixteenth-century Spanish and Portugese mathematicians.

Studies of Individual Mathematicians

When studying an individual mathematician, it is best to first consult the relevant article in the *Dictionary of Scientific Biography*, which usually contains a complete biography and bibliography of the most important sources up to its date of publication. The following list contains the most important works which have appeared since then or are worthy of special notice.

Agrippa von Nettesheim, Heinrich Cornelius (1486–1535)

1967. Molland, A. George. "Cornelius Agrippa's Mathematical Magic". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600*. Oxford: Clarendon Press, 1988, 209–219.

Discusses the mathematics in Agrippa's *De occulta philosophia* of 1533, particularly his number mysticism and use of magic squares.

Benedetti, Giovanni Battista (1530–1590)

1968. Bordiga, G. "Giovanni Battista Benedetti, filosofo e matematico veneziano del secolo XVI". *Atti del Reale Istituto Veneto di Scienze, Lettere ed Arte* 85 (part 2) (1925–1926), 585–754.

This is the fundamental mathematical biography of Benedetti.

1969. Maccagni, C. "Contributi alla biobibliografia di G. B. Benedetti". *Physis* 9 (1967), 337–364.

The most complete listing of information on Benedetti up to its date of publication.

1970. Field, J. V. "Giovanni Battista Benedetti on the Mathematics of Linear Perspective". *Journal of the Warburg and Courtauld Institutes* 48 (1985), 71–99.

An analysis of Benedetti's *De rationibus ... perspectiva* (1585) and Commandino's *Commentarius* (1558).

1971. Manno, Antonio, ed. *Cultura, Scienze e Tecniche nella Venezia del Cinquecento. Atti del Convegno Internazionale di Studi: Giovan Battista Benedetti e il suo tempo.* Venezia: Istituto Veneto di Scienze, Lettere ed Arti, 1987, 503 pp.

This conference volume contains 27 articles covering multiple aspects of Benedetti's life, work, and cultural ambience.

Bianchini, Giovanni (c.1400–c.1470)

1972. Rosińska, Grażyna. "Tables trigonometriques de Giovanni Bianchini". *Historia Mathematica* 8 no. 1 (1981), 46–55.

Description of two manuscripts at Cracow.

1973. Rosińska, Grażyna. "Giovanni Bianchini—15th Century Mathematician and Astronomer". *Zaklad Historii Nauki i Techniki. Kwartalnik Historii Nauki i Techniki* 26 no. 3-4 (1981-82), 565–577. In Polish.

A study of Bianchini's trigometrical tables compared to those of Copernicus and Regiomontanus.

1974. Rosińska, Grażyna. "The Algebra of Giovanni Bianchini in the Milieu of the Cracow Astronomers (XVth Century)". *Kwartalnik Historii Nauki* *i Techniki. Quarterly Journal of the History of Science and Technology* 39 no. 2 (1994), 3–19. In Polish.

Studies the algebra section in Bianchini's *Flore Almagesti* (1440-1454) and its influence.

Bombelli, Rafael (1526–1572)

1975. Bombelli, Rafael. *L'Algebra, Prima edizione integrale*. Milano: Feltrinelli, 1966, 671 pp.

This edition combines the text of the original edition of 1572 with the text of Books IV and V, which remained in manuscript and were first published by Ettore Bortolotti as *L'algebra, opera di Rafael Bombelli da Bologna. Libri IV e V comprendenti "La parte geometrica" inedita tratta dal manoscritto B. 1569, Biblioteca dell'Archiginnasio di Bologna*, (Bologna: Zanichelli, 1929). This "integral edition" also contains an introduction by Bortolotti.

1976. Hofmann, Joseph E. "Bombellis Algebra—eine genialische Einzelleistung und ihre Einwirkung auf Leibniz". *Studia Leibnitiana* 4 (1972), 196–252.

Contains a mathematical analysis of the *Algebra* and its influence on Leibniz in the areas of algebraic operations, equation theory, and Diophantine number theory.

1977. Jayawardene, S. A. "The Influence of Practical Arithmetics on the *Algebra* of Rafael Bombelli". *Isis* 64 (1973), 510–523.

Lists the practical problems found in the manuscript of Book III of the *Algebra* which were not included in the printed text. The author believes that their omission reflects the influence of Bombelli's discovery of Diophantus.

Bruno, Giordanno (1548–1600)

1978. Bönker-Vallon, Angelika. *Metaphysik und Mathematik bei Giordano Bruno*. Berlin: Akademie Verlag, 1995, xii + 281 pp.

A systematic study of Bruno's views on the relation between metaphysics and mathematics, emphasizing his critique of Aristotle, support of Plato and NeoPlatonism, and the influence of Cusa. Based on the author's Munich dissertation.

1979. Gatti, Hilary. "Minimum and maximum, Finite and Infinite: Bruno and the Northumberland Circle". *Journal of the Warburg and Courtauld Institutes* 48 (1985), 144–163.

Searches for the influence of Bruno on Thomas Harriot, Nicholas Hill, and other members of the Northumberland circle of English mathematicians.

Cardano, Girolamo (1501–1576)

1980. Cardano, Girolamo. *The Great Art, or the Rules of Algebra*. English translation by T. Richard Witmer. Cambridge, Mass.: MIT Press, 1968, 267 pp.

English translation with commentary of the first book to print the general solution to cubic and quartic equations.

1981. Bellini, Angelo. *Girolamo Cardano e il suo tempo*. Milan: U. Hoepli, 1947.

The only satisfactory biography of Cardano from the mathematician's point of view. It includes extensive bibliographic references.

1982. Vacca, G. "L'opera matematica di Girolamo Cardano nel quarto centenario del suo insegnamento in Milano". *Rendiconti, Seminario matematico e fisico di Milano* 11 (1937), 22–40.

Still worth consulting as a study of Cardano's mathematics.

1983. Kessler, Eckhard, ed. *Girolamo Cardano: Philosoph, Naturforscher, Arzt*. Wiesbaden: Otto Harrassowitz, 1994.

A collection of articles containing the most recent research on Cardano.

Chuquet, Nicolas (fl. 1484)

1984. Chuquet, Nicolas. "Le Triparty en la science des nombres par Maistre Nicolas Chuquet, parisien, d'après le manuscrit fonds français no. 1346 de la Bibliothèque Nationale de Paris". Edited by Aristide Marre. *Bullettino di bibliografia e storia delle scienze matematiche e fisiche* 13 (1880), 555–659, 693–814.

Chuquet's manuscript represents the summit of fifteenth-century French mathematics. This is still the only edition of the first part of the manuscript, the *Triparty* proper. A summary of the second part was published as the "appendix" to the *Triparty* in *Bullettino* 14 (1881), 413–460. The third part on geometry is published in item 1985. The fourth part remains unpublished.

1985. L'Huillier, Hervé. *Nicolas Chuquet La géométrie. Premiere géométrie algébrique en langue française (1484)*. Paris: J. Vrin, 1979, 491 pp.

The first edition of the geometry portion of Chuquet's manuscript, with introduction and notes.

1986. Flegg, Graham, Cynthia Hay, and Barbara Moss. *Nicolas Chuquet, Renaissance Mathematician*. Dordrecht: D. Reidel, 1985, viii + 388 pp.

Contains a partial English translation of all four parts of Chuquet's manuscript, with a historical introduction, analysis, and short bibliography. This is probably the best general introduction to the work of Chuquet at this time.

1987. Lambo, C. "Une algèbre française de 1484". *Revue des questions scientifiques* Series 3, (1902), 442–472.

Despite its age, contains the best analysis of Chuquet's entire work.

1988. Hay, Cynthia, ed. *Mathematics from Manuscript to Print 1300–1600.* Oxford: Clarendon Press, 1988.

The proceedings of a conference held on the quincentenary of the *Triparty*, it contains a number of articles relating to Chuquet's life and work. Particularly recommended are: Graham Flegg, "Nicolas Chuquet—An Introduction" (pp. 59–72); Guy Beaujouan, "The Place of Nicolas Chuquet in a Typology of Fifteenth-century French Arithmetics" (pp. 73–88); and Paul Benoit, "The Commercial Arithmetic of Nicolas Chuquet" (pp. 96–116).

Clavius, Christopher (1538–1612)

1989. Naux, Charles. "Le père Christophore Clavius (1537–1612): sa vie et son oeuvre". *Revue des Questions Scientifiques* 154 (1983), 55–67, 181–193, 325–347.

The most recent and thorough study of Clavius's life and works.

1990. Knobloch, Eberhard. "Sur la vie et l'oeuvre de Christophore Clavius (1538–1612)". *Revue d'Histoire des Sciences* 41 no. 3-4 (1988), 331–356.

Surveys his life and work, notes his opinion of Copernicus, and studies his combinatorial analysis, algebra, and number theory.

1991. Knobloch, Eberhard. "L'oeuvre de Clavius et ses sources scientifiques". In Luce Girard, ed. *Les Jésuites à la Renaissance: Système éducatif et production du savoir.* Paris: Presses Universitaires de France, 1995, 263–283.

Describes Clavius's publications and sources in mathematics and astronomy.

Copernicus, Nicholas (1473–1543)

1992. Swerdlow, N. M., and O. Neugebauer. *Mathematical Astronomy in Copernicus's De revolutionibus.* New York: Springer-Verlag, 1984, xvi + 711 pp. in 2 parts.

Copernicus is best known to the modern world for his cosmology—the first modern presentation of the heliocentric system. This is the definitive study of his technical, mathematical astronomy.

1993. Rossi, F. S. "Copernico matematico: La sua trigonometria piana". *Cultura e Scuola* 12 (1973), 317–336.

An elementary account of Copernicus's trigonometry.

Cusa, Nicholas of. See *Nicholas of Cusa*.

Dürer, Albrecht (1471–1528)

1994. Panofsky, Erwin. "Dürer as a Mathematician". In J. R. Newman, ed. *The World of Mathematics*. Vol. I. New York: Simon and Schuster, 1956, 603–621.

Gives a concise survey of perspective theory and Dürer's use of it.

1995. Steck, Max. *Dürer's Gestaltlehre der Mathematik und der bildenden Künste*. Halle and Tübingen: M. Niemeyer, 1948.

The best analysis of Dürer's mathematics, with an extensive bibliography. Summarized in the author's article in the *Dictionary of Scientific Biography*, Vol. IV, pp. 258–261.

1996. Schröder, Eberhard. *Dürer: Kunst und Geometrie*. Basel: Birkhäuser, 1980, 79 pp.

A careful study of Dürer's developing understanding and use of the mathematical principles of perspective.

1997. Peiffer, Jeanne. "Le style mathématique de Dürer et sa conception de la géométrie". In Joseph W. Dauben, Menso Folkerts, Eberhard Knobloch, and Hans Wussing, eds. *History of Mathematics: States of the Art. Flores quadrivii—Studies in Honor of Christoph J. Scriba*. San Diego: Academic Press, 1996, 49–61.

A study of the *Underweysung* and its sources, noting how Dürer's mathematical style alternates bewteen moving from the abstract to the concrete and from the practical to the abstract. The author sees Dürer's geometry as constructive rather than demonstrative.

1998. Walton, Karen Doyle. "Albrecht Dürer's Renaissance Connections between Mathematics and Art". *The Mathematics Teacher* 87 (1994), 278–282.

An elementary discussion of Dürer's use of perspective, magic squares, instruments, and the High German language.

Fibonacci, Leonardo. See *Leonardo da Pisa*.

Francesca, Piero della. See *Piero della Francesca*.

John of Gmunden (c. 1380–1442)

1999. Hamann, Günther, and Helmuth Grössing, eds. *Der Weg der Naturwissenschaft von Johannes von Gmunden zu Johannes Kepler*. (Österreichische Akademie der Wissenschaften, philosophisch-historische Klasse, Sitzungsberichte.) Vol. 497. Wien: Verlag der Österreichischen Akademie der Wissenschaften, 1988, 214 pp.

This volume contains two articles on this seminal figure in the revival of mathematics at the University of Vienna: Paul Uiblein, "Johannes von Gmunden. Seine Tätigkeit an der Wiener Universität" (pp. 11–64); and Hans K. Kaiser, "Johannes von Gmunden und seine mathematischen Leistungen" (pp. 85–100).

Kues, Nikolaus von. See *Nicholas of Cusa*.

Leonardo da Pisa, called (Fibonacci) (ca. 1170–ca. 1240)

2000. Boncompagni, B., ed. *Scritti di Leonardo Pisano*. Rome: Tipografia delle scienze matematiche e fisiche, 1857–1862. 2 vols.

Vol. I contains the *Liber abbaci*. Although published from a single manuscript with no editing, introduction, or commentary, this is still the only edition of this fundamental work of Renaissance mathematics. Vol. II contains the *Practicae geometriae* and other minor works, similarly without editing, introduction, or commentary.

2001. Ver Eecke, Paul. *Léonard de Pise: Le Livre des nombres carrés*. Bruges: Desclée, De Brouwer, 1952.

A French translation of the *Liber quadratorum*, with notes.

2002. Leonardo da Pisa. *The Book of Squares*. Boston: Academic Press, 1987, xx + 124 pp.

An annotated translation by L. E. Sigler with a brief biography. There is also a partial English translation in Edward Grant, ed., *A Source Book in Medieval Science*, item 1742, pp. 114–129.

2003. Picutti, Ettore. "The *Flos* of Leonardo Pisano". *Physis* 25 (1983), 293–387. In Italian.

An Italian translation of the shortest of Leonardo's works.

2004. Lüneberg, Heinz. *Leonardo Pisani Liber abbaci oder Lesevergnügen eines Mathematikers*. Mannheim: BI Wissenschaftsverlag, 1992, 352 pp. 2nd ed., 1993.

A reading of the mathematics in the *Liber abbaci* by a modern mathematician, full of mathematical, historical, and literary asides.

Leonardo da Vinci (1452–1519)

2005. Marinoni, Augusto. *La matematica di Leonardo da Vinci. Una nuova immagine dell'artista scienziato*. Milano: Philips-Arcadia, 1982,

This is the most recent book-length study of Leonardo's mathematics. A summary can be found in the author's article in the *Dictionary of Scientific Biography*, Vol. VIII, pp. 234–241. Marshall Clagett's discussion of Leonardo's mechanics on pp. 215–234 should also be consulted.

2006. Panofsky, Erwin. *The Codex Huygens and Leonardo da Vinci's Art Theory*. London: The Warburg Institute, 1940. Reprinted Westport, Conn.: Greenwood Press, 1971.

Studies Leonardo's mathematical interests related to theories of perspective and proportion.

2007. Bellone, Enrico, and Paolo Rossi, eds. *Leonardo e l'età della razione*. Milan: Scientia, 1982, xiv + 479 pp.

A recent collection of articles on many aspects of Leonardo's work.

2008. Fenyo, Istuan. "Leonardo da Vinci als Mathematiker". In S. D. Chatterji, et al., eds. *Jahrbuch Überblicke Mathematik 1985*. Mannheim: Bibliographisches Institut, 1983, 57–82.

A recent overview of Leonardo's mathematics.

2009. Elkins, James. "Did Leonardo Develop a Theory of Curvilinear Perspective? Together with Some Remarks on the 'Angle' and 'Distance' Axioms". *Journal of the Warburg and Courtauld Institutes* 51 (1988), 190–196.

The author disputes the claim that Leonardo developed a theory of curvilinear perspective and maintains that he knew only linear perspective. A technical and thoroughly documented introduction to an on-going controversy.

Maurolico, Francesco (1494–1575)

2010. Cassinet, Jean. "The First Arithmetic Book of Francisco Maurolico, Written in 1557 and Printed in 1575: A Step Towards a Theory of Numbers". In Cynthia Hay, ed. *Mathematics from Manuscript to Print 1300–1600*. Oxford: Clarendon Press, 1988, 162–179.

Surveys the contents of Maurolico's *Arithmeticorum* (1575) on number theory, mathematical induction, and the binomial formula.

Mercator, Gerardus (Kremer, Gerhard) (1512–1594)

2011. *Gerhard Mercator—1512–1594: zum 450. Geburtstag*. Vol. 6 (Duisburger Forschungen.) Duisberg: W. Renckhoff, 1962.

A collection of articles dealing with Mercator's life and works, issued on the occasion of the 450th anniversary of his birth.

2012. Vermij, Rienk, ed. *Gerhard Mercator und seine Welt*. Duisberg: Mercator Verlag, 1997.

A more recent collection of articles on Mercator and his time. Particularly notable is Gerhard Betsch, "Mercator als Mathematicus: Landvermessung und Kugelgeometrie im 16. Jahrhundert" (pp. 132–160).

Nicholas of Cusa (ca. 1401–1464)

2013. von Kues, Nikolaus. *Die mathematischen Schriften, übersetzt von Joseph Hofmann.* Leipzig: Felix Meiner, 1951–1952. 2 vols. 2nd edition Hamburg: Felix Meiner, 1980, lii + 270 pp.

Contains German translations of all his mathematical writings, even those not previously published. An extensive introduction by J. E. Hofmann provides the best overview of Cusa's mathematical work. A new edition of Nicolas of Cusa's mathematical works is being prepared by the Academy of Science in Heidelberg as part of the Nicolaus-von-Cusa-Gesamtausgabe.

2014. Nagel, Fritz. *Nikolaus Cusanus und die Entstehung der exacten Wissenschaften.* (Buchreihe der Cusanus-Gesellschaft, Band IX.) Münster: Aschendorff, 1984, vii + 192 pp.

A recent biography which pays particular attention to the role of mathematics in Cusa's work and his influence in the fifteenth and sixteenth centuries. Has a very complete bibliography. The first part deals with the foundation of a new way of thinking by Nicolaus of Kues (philosophy, metric ideas, conception of mathematics, beginning of functional thinking, experimental-scientific method). The second part traces the development and impact of these conceptions and ideas upon Regiomontanus, Stifel, Clavius, Cardano, Viète, Huygens, Descartes, Leibniz, and other mathematicians.

Nuñez, Pedro (1502–1578)

2015. Martin, John R. C. *Pedro Nunes (1503-1578): His Lost Algebra and Other Discoveries.* New York: Peter Lang, 1996, 158 pp.

Publishes the English translation of an algebra text found in an Éveira manuscript believed to be by Nunes, along with poems, letters, and religious texts found with it. Also includes a brief biography, analysis of the algebra text, and bibliography.

2016. Albuquerque, Luis. "Pedro Nunes and Diego de Sá". *Proceedings of the Eighth Portuguese-Spanish Conference on Mathematics (Coimbra, 1981).* Vol. IV. Coimbra: University of Coimbra, 1981, 9–31. In Portuguese.

A social history of the relationship between Nuñez and de Sá and their positions in the Portugese court.

Pacioli, Luca (1445–1517)

2017. Mackinnon, Nick. "The Portrait of Fra Luca Pacioli". *The Mathematical Gazette* 77 (479) (1993), 130–219.

A detailed analysis and discussion of the painting, its subject, and its milieu. With numerous plates and figures.

2018. Taylor, R. E. *No Royal Road: Luca Pacioli and His Times.* Chapel Hill: University of North Carolina Press, 1942.

This is the only book-length biography of Pacioli in English. Although historically unreliable, it makes interesting reading and provides a good sense of the time.

2019. Speziali, P. "Luca Pacioli et son oeuvre". In *Sciences de la Renaissance.* VIII^{e} *Congrès International de Tours.* Paris: J. Vrin, 1973, 93–106.

Provides a concise summary of his life and works.

Pereira, Benedictus (1535–1610)

2020. Giacobbe, Giulio Cesare. "A progressive Jesuit in the Renaissance "Quaestio de certitudine mathematicarum": Benito Pereyra". *Physis* 19 no. 1-4 (1977), 51–86. In Italian.

A study of Pereira's philosophy of mathematics in his *De communibus omnium rerum naturalium principiis et affectionibus* (1562). The author also compares it with Alessandro Piccolomini and Pietro Catena.

Piero della Francesca (ca. 1410–1492)

2021. Davis, Margaret D. *Piero della Francesca's Mathematical Treatises. The "Trattato d'abaco" and "Libellus de quinque corporibus regularibus".* Ravenna: Longo, 1977.

One of the most famous painters of the Italian Renaissance, Piero wrote three books on mathematics and perspective. This is a detailed study of the two mathematical works which focuses on their geometrical content and later use by Pacioli and other writers on perspective. It contains a good bibliography and is the best introduction to Piero's mathematics.

2022. Piero della Francesca. *Trattato d'abaco.* Edited by Gino Arrighi. Pisa: Domus Galileiana, 1970, 270 pp.

An edition of the text.

2023. Jayawardene, S. A. "The *Trattato d'abaco* of Piero della Francesca". In Cecil H. Clough, ed. *Cultural Aspects of the Italian Renaissance: Essays in Honour of Paul Oscar Kristeller. Manchester: Manchester University Press, 1976), 229–243.*

A study of the text.

2024. Giusti, Enrico. "L'algebra nel *Trattato d'abaco* di Piero della Francesca: osservazioni e congetture". *Bollettino di Storia delle Scienze Matematiche.* 11 no. 2 (1991), 55–83.

Studies the higher order equations in the text and compares them with those found in Leonardo, Dardi, Mazzinghi, and Pacioli.

2025. Giusti, Enrico. "Fonti medievali dell'*Algebra* di Piero della Francesca". *Bollettino di Storia delle Scienze Matematiche* 13 (1993), 199–250.

Compares Piero's algebra with excerpts from earlier abbacus manuscripts, finding many similarities. The author attributes this to a common tradition rather than to direct borrowing.

2026. Andersen, Kirsti. "Perspective and the Plan and Elevation Technique, in Particular in the Work by Piero della Francesca". In Sergei S. Demidov, Folkerts Menso, David E. Rowe, and Christoph J. Scriba, eds. *Amphora: Festschrift für Hans Wussing zu seinem 65. Geburtstag*. Basel: Birkhäuser, 1992, 1–23.

Analyzes Piero's use of this technique in the *De perspectiva pingendi* and in later authors until it was adopted by descriptive geometry in the nineteenth century.

2027. Stoller, Diethelm. "Piero della Francesca—der Maler als Mathematiker". In *Mathematikdidaktik, Bildungsgeschichte, Wissenschaftsgeschichte, II (Georgsmarienhutte, 1986)*. Köln: Aulis/Deubner, 1990, 17–35.

Analysis of Piero's *De perspectiva pingendi*.

2028. Field, J. V. "A Mathematician's Art". In Marilyn A. Lavin, ed. *Piero della Francesca and His Legacy*. Washington: National Gallery of Art, 1995, 177–198.

A study of the *De perspectiva pingendi* and Piero's use of perspective in his art.

Müller, Johannes called Regiomontanus (1436–1476)

2029. Zinner, Ernst. *Regiomontanus: His Life and Work*. Translated by Ezra Brown. Amsterdam: North-Holland, 1990, x + 402 pp.

Regiomontanus is the key figure in the German Renaissance of mathematics. Zinner's carefully documented study of every aspect of his life and work makes this the indispensable foundation for all research. This translation is accompanied by a series of supplements updating Zinner's work the latest scholarship on Regiomontanus, making it far preferable to the second German edition, *Leben und Wirken des Johannes Müller von Königsberg gennant Regiomontanus*, Osnabrück: O. Zeller, 1968.

2030. Schmeidler, Felix, ed. *Joannis Regiomontani opera collectanea*. Osnabrück: O. Zeller, 1972.

Includes a biography by the editor.

2031. Hughes, Barnabas. *Regiomontanus on Triangles. De triangulis omnimodis by Johann Müller, otherwise Known as Regiomontanus.* Madison: University of Wisconsin Press, 1967.

Latin text with English translation and notes of the fundamental text of Renaissance trigonometry. A short introduction sets the historical background. See also item 1746.

2032. Folkerts, Menso. "Regiomontanus als Mathematiker". *Centaurus* 21 (1977), 214–245.

Gives the best short overview of Regiomontanus's mathematics.

2033. Hamann, Günther, ed. *Regiomontanus-Studien.* Wien: Verlag der Österreichischen Akademie der Wissenschaften, 1980, 448 pp.

This indispensable volume contains a large number of articles dealing with various aspects of Regiomontanus's life and works.

2034. Folkerts, Menso. "Regiomontanus als Vermittler algebraischen Wissens". In Menso Folkerts, and Uta Lindgren, eds. *Mathemata. Festschrift für Helmuth Gericke.* Wiesbaden: Franz Steiner, 1985, 207–219.

Background and brief summary of the 62 algebra problems in Plimpton 188, ff. 73r-96r, written by Regiomontanus in 1456.

2035. Swerdlow, N. M. "Science and Humanism in the Renaissance: Regiomontanus's *Oration on the Dignity and Utility of the Mathematical Sciences.*" In Paul Horwich, ed. *World Changes: Thomas Kuhn and the Nature of Science.* Cambridge: The MIT Press, 1993, 131–168.

An analysis of the 1464 oration and his printing prospectus reveal the influence of humanism in Regiomontanus's mathematics.

2036. Gerl, Armin. *Trigonometrisch-astronomisches Rechnen kurz von Copernicus. Der Briefwechsel Regiomontanus–Bianchini.* Vol. 21. (Boethius.) Stuttgart: Franz Steiner, 1989, 357 pp.

A new edition of this important correspondence.

2037. Glowatzki, Ernst, and Helmut Göttsche. *Die Tafeln des Regiomontanus. Ein Jahrhundertwerk.* München: Institut für Geschichte der Naturwissenschaften, 1990, 224 pp.

A detailed study of his trigonometric tables, their sources and influence.

Ries, Adam (1492–1559)

2038. Wussing, Hans. *Adam Ries.* Vol. 95. (Biographien hervorragender Naturwissenschaftler.) Leipzig: Teubner, 1989, 114 pp.

The most recent book-length biography.

2039. Wussing, Hans. "Adam Ries—Rechenmeister und Cossist". *Österreichische Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Klasse. Sitzungsberichte. Abteilung II. Mathematische, Physikalische und Technische Wissenschaften.* 195 no. 1-3 (1986), 195–211.

A short biography that examines Ries's sources, competence, and place in the development of algebra.

2040. Deschauer, Stefan. *Das zweite Rechenbuch von Adam Ries.* Braunschweig: Friedr. Vieweg & Sohn, 1992, xiv + 237 pp.

A translation into modern German of the *Rechenung auff der linihen und federn* of 1522, the most widely reprinted German arithmetic.

2041. Ries, Adam. *Coss. Faksimile.* Stuttgart: B. G. Teubner, 1992, 536 pp.

A facsimile edition of three manuscripts in Annaberg comprising the 1524 version of the *Coss*, the 1545-50 *Coss*, and a German excerpt of the *De numeris datis* of Jordanus Nemorarius.

2042. Ries, Adam. *Coss. Kommentar.* Edited by Wolfgang Kaunzner, and Hans Wussing. Stuttgart: B. G. Teubner, 1992, 138 pp.

A discussion and analysis of the three texts listed in the preceeding, with a good biographical and historical introduction.

2043. Gebhart, Rainer. *Einblicke in die Coss von Adam Ries.* Leipzig: Teubner, 1994, 201 pp.

Excerpts and translations from the Annaberg manuscripts with commentary.

2044. Kaunzner, Wolfgang. "Über die beiden nachgelassenen mathematischen Handschriften von Adam Ries". In M. Folkerts, and J. P. Hogendijk, eds. *Vestigia Mathematica. Studies in Medieval and Early Modern Mathematics in Honour of H. L. L. Busard.* Amsterdam: Rodopi, 1993, 173–204.

A study of Ries's algebra as found in the two versions of the *Coss* and Dresden manuscript C 349.

Roomen, Adriaan van (1561–1615)

2045. Bockstaele, Paul. "The Correspondence of Adriaan van Roomen. *Lias* 3 (1976), 85–129, 249–299. "

Prints 41 Latin letters.

2046. Bockstaele, Paul. "The Correspondence of Adriaan van Roomen: Corrections and additions, 1594-1615". *Lias* 19 (1992), 3–20.

Prints an additional 7 Latin letters and makes some corrections to those printed in 1976.

2047. Bockstaele, Paul. "Adrianus Romanus and the Trigonometric Tables of Georg Joachim Rheticus". In Sergei S. Demidov, Folkerts Menso, David E. Rowe, and Christoph J. Scriba, eds. *Amphora: Festschrift für Hans Wussing zu seinem 65. Geburtstag.* Basel: Birkhäuser, 1992, 55–66.

Examines Romanus's (Adriaan van Roomen's) reaction to the publication of Rheticus's *Opus palatinum* (1596).

Scheubel, Johann (1494–1570)

2048. Day, Mary S. *Scheubel as an Algebraist; Being a Study of Algebra in the Middle of the Sixteenth Century, Together with a Translation of and a Commentary upon an Unpublished Manuscript of Scheubel's, Now in the Library of Columbia University.* New York: Teachers College, Columbia University, 1926. Reprinted New York: AMS Press, 1972.

Still a useful study of Scheubel's life, works, and influence, although the author's survey of earlier German algebra has been superseded by more recent research.

2049. Reich, Ulrich. "Johann Scheubel (1494-1570): Geometer, Algebraiker und Kartograph". In Irmgard Hantsche, ed. *Der "mathematicus". Zur Entwicklung und Bedeutung einer neuen Berufsgruppe in der Zeit Gerhard Mercators.* Vol. 4. (Duisburger Mercator-Studien, 4.) Bochum: Brockmeyer, 1996, 141–182.

A more recent biography designed to replace Day.

Stevin, Simon (1548–1620)

2050. Dijksterhuis, E. J. *Simon Stevin.* The Hague: M. Nijhoff, 1943, xii + 379 pp. English translation by the author as *Simon Stevin: Science in the Netherlands around 1600.* The Hague: M. Nijhoff, 1970, ix + 145 pp.

Includes chapters on his mathematics and mechanics. See item 2209.

2051. Struik, Dirk J., ed. *The Principal Works of Simon Stevin.* Amsterdam: Swets & Zeitlinger, 1958, 976 pp.

The introductions to each work set them in their historical perspective.

2052. Depau, R. *Simon Stevin.* Brussels: J. Lebèque & Cie., 1942. In French.

The best biography of Stevin, with a good bibliography.

Stifel, Michael (ca. 1487–1567)

2053. Hofmann, Joseph E. "Michael Stifel (1487?-1567). Leben, Wirken und Bedeutung für die Mathematik Seiner Zeit". *Sudhoffs Archiv* Beiheft 9, (1968), 42 pp.

The best biography of Stifel.

2054. Stifel, Michael. *Arithmetica integra. Esslinger Studien* 28 (1989), 75–129.

A partial translation of the text from Latin to German with a historical commentary.

2055. Röttel, Karl. "Der mathematiker Michael Stifel. Algebra in den Anfängen". *Praxis der Mathematik* 29 no. 8 (1987), 493–500.

A brief description of the mathematical content of the *Arithmetica integra* (1544) and *Deutsche mathematica* (1545).

2056. Reich, Karin. "Michael Stifel: zwischen Rechenmeistertradition und Mathematik als Wissenschaft". *Mitteilungen der Mathematischen Gesellschaft in Hamburg* 14 (1995), 23–33.

Summary of Stifel's life, work, and influence.

Tartaglia, Niccolò (1499–1557)

2057. Tartaglia, Niccolò. *Quesiti et inventioni diverse. Riproduzione in facsimile dell'edizione del 1554.* Edited by Arnaldo Masotti. Brescia: Ateneo di Brescia, 1959, lxxxv + 128 pp.

A facsimile of Tartaglia's most important work on mathematics and mechanics.

2058. Masotti, Arnaldo, ed. *Cartelli di sfida matematica. Riproduzione in facsimile delle edizioni originali 1547–1548.* Brescia: Ateneo di Brescia, 1974, cxciii + 202 pp.

The correspondence between Tartaglia and Ludovico Ferrari recounts the dispute between the former and Cardano over who should receive credit for discovering the solution to the cubic equation. Masotti's commentary contains a well-documented introduction, an index of names, a chronology, and a glossary of archaic terms.

2059. Masotti, Arnaldo. *Studi su N. Tartaglia.* Brescia, 1962.

The best one-volume study of Tartaglia, with a good bibliography. See the author's summary article in the *Dictionary of Scientific Biography*, Vol. XIII, pp. 258–262.

2060. Schultz, Phillip. "Tartaglia, Archimedes and cubic equations". *The Australian Mathematical Society Gazette* 11 no. 4 (1984), 81–84.

Attempts a reconstruction of Tartaglia's solution of the cubic. Argues that it was based on geometrical rather than algebraic analysis, based on a problem found in Archimedes's *Sphere and cylinder.*

Toscanelli, Paolo dal Pozzo (1397–14820)

2061. Jervis, Jane L. "The Mathematics of Paolo Toscanelli". *Annali dell'Istituto e Museo di Storia della Scienza* 4 no. 1 (1979), 3–14.

Analyzes the mathematics used by Toscanelli on a page of cometary observations in 1433, showing his facility with spherical trigonometry and the use of sexagesimal fractions.

Valerio, Luca (1552–1618)

2062. Napolitani, Pier Daniele. “Method and Statics in Valerio, with Editions of Two Early Works”. *Bollettino di Storia delle Scienze Matematiche* 2 no. 1 (1982), 3–86. In Italian.

Careful study and analysis of Valerio’s mathematical works which sees him as a classical mathematician. The same volume includes editions of his *Phylogeometricus tetragonismus* (pp. 87–120), and *Subtilium indagationum liber primus* (pp. 121–173).

2063. Baldini, Ugo, and Pier Daniele Napolitani. “Toward a Biography of Luca Valerio: Published and Unpublished Sources for a Reconstruction of His Scientific Career”. *Bollettino di Storia delle Scienze Matematiche* 11 no. 1 (1991), 157 pp. In Italian.

Argues for the importance of Valerius in 16th-century Italian mathematics, and identifies the sources that can be used to establish the facts of his life and career.

Viète, François (1540–1603)

2064. Viète, François. *Opera mathematica*. Edited by Francis Schooten. Hildesheim: Georg Olms Verlag, 1970, xxxix + 544 pp.

Facsimile reprint of the 1646 Leiden edition. Pages v– xxx contain an introduction and index by Joseph E. Hofmann

2065. Viète, François. *The Analytic Art*. Translated by T. Richard Witmer. Kent, OH: Kent State University Press, 1983, 450 pp.

English translation of the 9 texts of Viète’s algebra.

2066. Viète, François. *Einführung in die neue Algebra*. Edited by Karin Reich, and Helmuth Gericke. Munich: Werner Fritsch, 1973, 145 pp.

Translation into German of the *In artem analyticem isagoge* and abridged translations of the *Ad logisticem speciosam notae priores* and *Zeteticorum liber quinque*, with commentaries and a historical introduction.

2067. Freguglia, Paolo. “Algebra e geometria in Viète”. *Bollettino di Storia delle Scienze Matematiche* 9 no. 1 (1989), 49–90.

Looks for attempts to “geometricize” algebra through the use of proportions in Viète, Stevin, Bombelli, and Paolo Bonasoni. The author also offers a new interpretation of Viète’s exegetics.

2068. Giusti, Enrico. "Algebra and Geometry in Bombelli and Viète". *Bollettino di Storia delle Scienze Matematiche* 12 no. 2 (1992), 303–328.

Constructs solutions of 1st, 2nd, and 4th degree equations from Book IV of Bombelli and the *Effectionium geometricarum* of Viète.

2069. Freguglia, Paolo. "Sur la théorie des équations algébriques entre le XVI et le XVII siècle". *Bollettino di Storia delle Scienze Matematiche* 14 no. 2 (1994), 259–296.

A study of the geometrical reasoning that underlies the algebra of Viète, particularly in the *De recognitione et emendatione aequationum*, with a brief comparison to Cardano, Bombelli, and Descartes.

2070. Brigaglia, Aldo, and Pietro Nastasi. "Apollonian Reconstructions in Viète and Ghetaldi". *Bollettino di Storia delle Scienze Matematiche* 6 no. 1 (1986), 83–133.

Examines their attempts to reconstruct problems from Apollonius, particularly those dealing with verging and tangent constructions. Also mentions the work of Girard and Descartes.

Vinci, Leonardo da. See *Leonardo da Vinci*.

MATHEMATICS IN THE 17th CENTURY

This section has been divided into a number of categories. Much of the literature covered here represents a larger period than the 17th century, although in this section titles have only been annotated for their content about the 17th century. In the section devoted to individual mathematicians, only titles which supply a general impression of the more important mathematicians' significant works are included.

General

2071. Bos, H. J. M. *Lectures in the History of Mathematics.* Providence, R.I., London: American Mathematical Society/ London Mathematical Society, 1993, x + 197 pp.

A collection of essays. The central themes are: when was a problem considered solved, and when was an object (such as a curve) considered to be known. The topics range from the 17th to the 19th century. Among the mathematicians whose work is analyzed are Descartes, Huygens, Leibniz, the Bernoullis, and Poncelet.

2072. Feingold, Mordechai. *The Mathematician's Apprenticeship: Science, Universities and Society in England, 1560–1640.* Cambridge: Cambridge University Press, 1984, viii + 248 pp.

The author's intention is "to demonstrate that the English universities contributed significantly to the critical dialogue that vitalized the scientific community" in the period under consideration, and that the traditional view, that they were inimical to new scientific modes of thought is unfounded.

2073. Whiteside, D. T. "Patterns of Mathematical Thought in the Later Seventeenth Century". *Archive for History of Exact Sciences* 1 (1960–1962), 179–388.

This very rich monograph approaches 17th-century mathematics with a primary interest in mathematical structures and methods of proof. It emphasizes the work of British mathematicians. The three largest sections concern the concept of function, geometry, and the calculus.

2074. Zeuthen, H.-G. *Geschichte der Mathematik im 16. und 17. Jahrhundert.* Leipzig: Teubner, 1903. Reprinted New York: Johnson Reprint Corporation, 1966, viii + 434 pp.

More than three-quarters of this book is devoted to 17th-century mathematics. Though rather dated, the *Geschichte* is a useful general survey of the period, and it contains penetrating comments on a number of 17th-century mathematical texts. See also item 1872.

Algebra

2075. Pycior, Helena M. *Symbols, Impossible Numbers, and Geometric Entanglements. British Algebra through the Commentaries on*

Newton's Universal Arithmetick. Cambridge: University Press, 1973, xi + 328 pp.

The first history of the development and reception of algebra in early modern England and Scotland, this book does not concentrate on the technical aspects. Its aim is to analyze the complex web of mathematical, philosophical and religious motivations that contributed to the acceptance of a symbolic style of thinking (and of negative and imaginary numbers) at the expense of the predominant geometrical one. While Newton's central role is emphasized, equally covered are Oughtred, Harriot, Pell, Wallis, Hobbes, Barrow, Berkeley, Maclaurin, and Saunderson.

Analysis and Calculus

2076. Baron, Margaret E. *The Origins of the Infinitesimal Calculus*. Oxford: Pergamon, 1969, viii + 304 pp. Reprinted New York: Dover, 1987, 304 pp. (Unaltered paperback edition.)

Traces the history of methods and techniques for the determination of tangents, maxima and minima, centers of gravity, areas, volumes and arc-lengths developed before Newton and Leibniz. The book gives many detailed examples from the 17th century. It ends with an epilogue about the early works of Newton and Leibniz.

2077. Bos, H. J. M. "Differentials, Higher-Order Differentials and the Derivative in the Leibnizian Calculus". *Archive for History of Exact Sciences* 14 (1974–1975), 1–90.

A study of the theory, the techniques, and the underlying concepts of the infinitesimal calculus as practiced by Leibniz and his early followers. It discusses in particular the higher-order differentials, the treatment of which revealed several conceptual difficulties about differentials (e.g., their indeterminate character). The difference between the Leibnizian and the modern calculus is stressed (pp. 34–35): the former was a calculus of variables, the latter is one of functions.

2078. Boyer, Carl B. *The History of the Calculus and Its Conceptual Development*. New York: Dover, 1959; first published as *The Concepts of the Calculus, a Critical and Historical Discussion of the Derivative and the Integral*. New York: Columbia University Press, 1939, vi + 346 pp. Reprinted New York: Hafner, 1949.

This book is still the basic comprehensive history of the calculus. The comments on the foundations of earlier calculus methods are not the strongest side of the book, but it is valuable because of its extensive coverage of primary and (up to ca. 1940) secondary sources. Chapters IV and V (pp. 96–223) concern the 17th century. See also item 4056.

2079. Cuestra Dutari, Norberto. *La invensión del cálculo infinitesimal y su introducción en España.* Salamanca Ediciones de la Universidad de Salamanca, 1984.

The invention of the infinitesimal calculus and its introduction in Spain. Beginning with the Newton and Leibniz controversy, the book relates the introduction and teaching of calculus in Spain.

2080. Edwards, C. H., Jr. *The Historical Development of the Calculus.* New York, Heidelberg, Berlin: Springer Verlag, 1979, xii + 351 pp.

Special features of this history of calculus are its interest in techniques (evident, e.g., in a separate chapter on Napier's logarithms) and the inclusion of many exercises which, if worked out by the reader, convey parts of the story. Chapters 4–9 (pp. 98–267) concern 17th-century developments.

2081. Goldstine, Herman H. *A History of the Calculus of Variations from the 17th through the 19th Century.* New York, Heidelberg, Berlin: Springer, 1980, xviii + 410 pp.

Chapter 1 (66 pp.) traces the origins from Fermat's principle to the work of the brothers Bernoulli.

2082. Grattan-Guinness, Ivor, ed. *From the Calculus to Set Theory, 1630–1910. An Introductory History.* London: Duckworth, 1980, 306 pp.

Six chapters by different authors on the history of mathematical theories involving the infinite. Chapter I, "Techniques of the Calculus, 1630–1660" (pp. 10–48) by Kirsti Møller Pedersen, surveys calculus techniques before Newton and Leibniz, stressing the ideas underlying the various 17th-century methods of determining areas under curves and tangents to curves. Chapter II, "Newton, Leibniz and the Leibnizian Tradition" (pp. 49–93) by H. J. M. Bos, sketches Newton's and Leibniz's "discoveries" of the calculus and the development of the Leibnizian calculus till 1780, concentrating on the fundamental concepts.

2083. Hofmann, Joseph E. "Zur Entdeckungsgeschichte der höheren Analysis im 17. Jahrhundert". *Mathematisch-physikalische Semesterberichte* 1 (1950), 220–255.

Valuable survey, rich in factual information about persons and sources. But the characterizations of the achievements are often so compact (in particular because of the use of modern notation) that they can hardly be understood without further study of the sources.

2084. Hofmann, Joseph E. "Über Auftauchen und Behandlung von Differentialgleichungen im 17. Jahrhundert" *Humanismus und Technik* 15, (Part 3), (1972), 1–40.

The article traces the history of the so-called "problem of Debeaune" (in modern terms, the differential equation $ay' = x - y$) from Descartes to the Bernoullis, thus providing examples of various approaches to problems involving differential equations which were developed in the 17th century. See also item 2908.

2085. Malet, Antoni. *From Indivisibles to Infinitesimals. Studies on Seventeenth-Century Mathematizations of Infinitely Small Quantities.* Bellaterra: Universitat Autònoma de Barcelona, Servei de Publicacions, 1996, 163 pp.

Starting with Cavalieri, the author analyzes in detail the works of Pascal, Barrow, Wallis, Boulliau, Huygens, Gregorie (James Gregory), Newton, before turning in particular to the method of tangents. The final chapter reviews the method of indivisibles in its philosophical context, arguing that "the main strength of the method was its dovetailing with key elements of the mechanical philosophy."

2086. Naux, C. *Histoire des logarithmes de Neper à Euler.* Paris: Blanchard, 1966–1971, 158 + 230 pp. 2 vols.

Extensive description of the invention of logarithms, the calculation of the first tables, and the study of the logarithmic relation within the development of analysis.

2087. Reiff, R. *Geschichte der unendlichen Reihen.* Munich: Urban & Schwarzenberg, 1889. Photographically reprinted Wiesbaden: Martin Sändig, 1969, iv + 212 pp.

The book (of which Chapter I [pp. 4–63] treats of 17th-century developments) is useful as a collection of summaries of texts on series. It should be kept in mind that after 1889 our knowledge of the sources has grown considerably.

Geometry

2088. Boyer, Carl B. *History of Analytic Geometry.* New York: Scripta Mathematica, 1956, ix + 291 pp.

A useful survey of the development of analytic geometry (Chapters IV–VII, pp. 54–191, deal with the 17th century), based on a wide range of primary and secondary sources (see the valuable "analytical bibliography"). The book traces primarily the history of those parts of analytic geometry that can be found in mid-20th-century college textbooks. This viewpoint occasionally leads to an anachronistic treatment and judgment of the material.

2089. Coolidge, J. L. *A History of Geometrical Methods.* Oxford: Oxford University Press, 1940. Reprinted New York: Dover, 1963, xviii + 451 pp.

Concerning the 17th century the book contains short surveys of the works of Desargues and Pascal on projective geometry, and of the contributions of Fermat, Descartes, Wallis, Barrow, and Newton to algebraic geometry.

2090. Edgerton, Samuel Y. *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution.* Ithaca, N.Y./London: Cornell University Press, 1991, xii + 319 pp.

See item 3583.

2091. Fladt, Kuno. *Geschichte und Theorie der Kegelschnitte und der Flächen zweiten Grades.* Stuttgart: Klett, 1965, x + 374 pp.

This book comprises both a historical and a theoretical treatment of the conic sections and the surfaces of degree 2. Chapter 3 of the first part contains a sketch of the development from the 16th to the 18th century.

2092. Mainzer, Klaus. *Geschichte der Geometrie.* Mannheim, Vienna, Zürich: Bibliographisches Institut, 1980, 232 pp.

Chapter 4 (pp. 92–133) deals with geometry in the 17th and 18th centuries.

2093. Loria, Gino. "Perspektive und darstellende Geometrie". In *Geschichte der Mathematik.* Vol. 4. Edited by M. Cantor. Leipzig: B. G. Teubner, 1908, 579–622. Revised and translated into Italian by Gino Loria. *Storia della geometria descrittiva.* Milan: Ulrico Hoepli, 1921, 1–96.

This chapter contains a description of 17th-century literature on the theory of perspective and perspective constructions.

Number Theory

No survey exists of the development of number theory in the 17th century; however, contributions of mathematicians from this period can be found in the following books:

2094. Dickson, L. E. *History of the Theory of Numbers.* Washington, D.C.: The Carnegie Institution, 1919–1923. Reprinted New York: Stechert, 1934, and New York: Chelsea, 1952, 1971. 3 vols., xii + 486 + 803, iv + 313 pp.

See item 3458.

2095. Ore, Øystein. *Number Theory and Its History.* New York, Toronto, London: McGraw-Hill, 1948, x + 370 pp.

See item 3479.

2096. Bašmakova, I. G. *Diophant und diophanatische Gleichungen.* Basel, Stuttgart: Birkhäuser (without year), and Berlin: VEB Deutscher Verlag der Wissenschaften, 1974, 97 pp.

In the second part of the book the author traces how the method of Diophantos was rediscovered and elaborated by Viète, Fermat, and later mathematicians.

2097. Hofmann, Joseph E. "Über zahlentheoretische Methoden Fermats und Eulers, ihre Zusammenhänge und ihre Bedeutung". *Archive for History of Exact Sciences* 1 (1960–1962), 122–159.

Beginning with a summary of Fermat's essential results in the theory of numbers, the author discusses several selected problems (some of which he had studied in earlier papers in detail) before he describes Fermat's and Euler's general procedures. He finally gives a unified treatment by means of the Weierstrass $\wp$-function. See also item 3471.

Probability and Statistics

2098. Hacking, Ian. *The Emergence of Probability.* Cambridge: Cambridge University Press, 1975, 209 pp.

Considers the philosophical aspects of early ideas of probability and statistical inference. Most of the book is devoted to 17th-century incidents.

2099. Maistrov, L. E. *Probability Theory. A Historical Sketch.* Translated by S. Kotz from *Teoriià Veroiàtnosteĭ Istoricheskiĭ Ocherk*, Moscow, 1967. New York and London: Academic Press, 1974, xi + 281 pp.

The first two chapters contain about 30 pages treating the contribution of the 17th century to the development of probability theory.

2100. Pearson, Karl. *The History of Statistics in the 17th and 18th Centuries.* Edited by E. S. Pearson. London: Charles Griffin, 1978, xix + 744 pp.

The book contains lectures given by Karl Pearson in the period 1921–1933. The first 124 pages are devoted to the 17th century and describe the founding of the English school of political arithmetic and the correspondence between Caspar Neumann and Edmund Halley.

2101. Westergaard, Harald. *Contributions to the History of Statistics.* London: P. S. King & Son, 1932. Photomechanically reprinted 1969, vii + 280 pp.

Contains a chapter on political arithmetic in the seventeenth century.

Special Studies and Individual Mathematicians

2102. Cajori, Florian. *A History of the Logarithmic Slide Rule and Allied Instruments.* New York: The Engineering News Publishing Company, 1909. Reprinted in *String Figures and Other Monographs.* Edited by W. W. R. Ball et al. New York: Chelsea Publishing Company, 1960, 1969, vi + 136 pp.

The first 24 pages of Cajori's booklet deal with the origin of the slide rule in the 17th century. In the reprinted Chelsea edition, Cajori's monograph follows three others; the volume is not consecutively paginated. Cajori's study is the last in the book, is well illustrated, and contains a catalogue of slide rules as well as a bibliography on the subject.

2103. Cohen, H. Floris. *Quantifying Music. The Science of Music at the First Stage of the Scientific Revolution, 1580–1650.* Dordrecht, Boston, Lancaster: D. Reidel Publ. Co., 1984, xvii + 308 pp.

In the 16th century the Pythagorean theory of harmony was replaced by Renaissance theories justifying the use of the third. The author discusses the mathematical (Kepler, Stevin), the experimental (Benedetti, the Galileos, Mersenne) and the mechanistic (Beeckman, Descartes), attempts to study music as a science, and the victory of Huygens's explanation of consonances as coincidences.

2104. Goldstine, Herman H. *A History of Numerical Analysis from the 16th through the 19th Century.* New York, Heidelberg, Berlin: Springer-Verlag, 1977, xiv + 348 pp.

The first two chapters (pp. 1–118) provide a survey of 17th-century numerical techniques concerning logarithms, interpolation, finite differences, trigonometric tables, the "Newton-Raphson method", and methods of numerical integration. See also item 3516.

2105. Loria, Gino. *Spezielle algebraische und transzendente ebene Kurven. Theorie und Geschichte.* Leipzig: Teubner, 1902, xxi + 744 pp. 2 vols.

The book is very useful for the study of curves dealt with in the 17th century. It accounts for the history and the properties of the plane curves which have played an important role in the development of the theory of curves.

2106. Schneider, Ivo. "Der Einfluss der Praxis auf die Entwicklung der Mathematik vom 17. bis zum 19. Jahrhundert". *Zentralblatt für Didaktik der Mathematik* 9 (1977), 195–205.

Schneider discusses the methodological difficulties in assessing the influence of practice on the development of mathematics, and he presents many examples in which this influence can be discerned. See also item 4021.

2107. Taylor, Eva G. R. *The Mathematical Practitioners of Tudor and Stuart England, 1485–1714.* Cambridge: Cambridge University Press, 1954, xi + 443 pp., 12 pls.

Very important study of 17th-century mathematics teachers, textbook writers, and other practitioners of the mathematical arts. Offers a general survey of the development within this mathematical profession, as well as short biographies of 528 mathematical practitioners and an annotated bibliography listing 628 contemporary works. In 1966 a sequel to this book appeared, covering the 18th and early 19th centuries:
E. G. R. Taylor, *The Mathematical Practitioners of Hanoverian England 1714–1840*, item 2303. See also item 1959.

Barrow, Isaac (1630–1677)

2108. Feingold, Mordechai, ed. *Before Newton. The Life and Times of Isaac Barrow.* Cambridge, New York: Cambridge University Press, 1992, xi + 380 pp.

A collection of studies by six authors, dealing with the biography, Barrow's *Optical Lectures* (Alan E. Shapiro), his mathematics (Michael S. Mahoney), the academic milieu, Barrow as a scholar and as a preacher, and a reconstruction of his library.

2109. Zeuthen, H.-G. "Notes sur l'histoire des mathématiques, VII. Barrow, le maître de Newton". *Oversigt over der Kgl. Danske Videnskabernes Selskabs Forhandlinger* (1897), 565–606.

Discusses the extent to which Barrow had realized the connection between quadratures and the determination of tangents.

Bernoulli, Jakob (1654–1705) and Bernoulli, Johann (1667–1748)

2110. Dietz, P. "Die Ursprünge der Variationsrechnung bei Jakob Bernoulli". *Verhandlungen der naturforschenden Gesellschaft in Basel* 70 (1959), 81–146.

This is an extensively annotated edition of those parts of Jakob Bernoulli's scientific diary which relate to variational problems.

2111. Fleckenstein, J. O. *Johann und Jakob Bernoulli.* (Supplement No. 6 to the journal *Elemente der Mathematik.*) Basel: Birkhäuser, 1949, 24 pp.

This short brochure gives biographical information and provides a detailed discussion of a number of problems (especially in variational calculus) that were treated by the brothers Bernoulli.

2112. Hofmann, Joseph E. *Ueber Jakob Bernoullis Beiträge zur Infinitesimalmathematik.*(Monographies de l'enseignement mathématique, No. 3.) Geneva: Institut de Mathématiques, Université, 1956, 126 pp.

This compact monograph is not easily readable, but with its 389 notes (pp. 57–96) and its indices of names, sources, and subjects it is a very rich source of factual information about mathematics in the period around 1700.

Cavalieri, Bonaventura (1598–1647)

2113. Cavalieri, Bonaventura. *Geometria degli indivisibili.* Translated and edited by Lucio Lombardo-Radice. Turin: Unione Tipografico-Editrice Torinese, 1966, 870 pp.

The *introduzione* and *nota bibliografica* (pp. 9–37) are useful for information about Cavalieri's mathematical work.

2114. Andersen, Kirsti. "Cavalieri's Methods of Indivisibles". *Archive for History of Exact Sciences.* 31 (1985), 291–367.

A detailed presentation of the fundamental ideas, concepts, and techniques involved in Cavalieri's method. The author further describes how Cavalieri's mathematical concept of "all the lines" has been misunderstood from the 17th through the 20th centuries.

2115. Giusti, Enrico. *Bonaventura Cavalieri and the Theory of Indivisibles.* Bologna: Edizioni Cremonese, 1980, 95 pp.

This is a special issue of the introduction to the 1980 reprint of Cavalieri's *Exercitationes geometricae sex* giving an excellent survey of Cavalieri's ideas and the difficulties inherent in his concepts.

2116. Masotti, S. C. Arnaldo. "Commemorazione di Bonaventura Cavalieri". *Rendiconti dell'Istituto Lombardo di scienze e lettere, parte generale e atti ufficiali* 81 (1948), 43–86. Also as a separate print, Milano: Ulrico Hoepli, 1949.

The appendix I, *Scritti di Bonaventura Cavalieri* gives an exact list of Cavalieri's works, and the second appendix carefully surveys the secondary literature about Cavalieri up to 1948.

2117. Piola, Gabrio. *Elogio di Bonaventura Cavalieri.* Milan: Giuseppe Bernadoni di Giovanni, 1844, xxxi + 155 pp.

This is the source for most later biographies on Cavalieri.

Clavius, Clavius (1538–1612)

2118. Knobloch, Eberhard. "Christoph Clavius. Ein Namen- und Schriftenverzeichnis zu seinen *Opera mathematica*". *Boll. Storia Sci. Math.* 10, no. 2 (1990), 135–189.

A very useful 682-entry index of names and publications quoted by Clavius in the five volumes of his *Opera* (Mainz, 1611–1612). Apart from numerous other persons, more than 130 mathematicians and astronomers are identified.

Desargues, Girard (1591–1661)

2119. Desargues, Gérard *The Geometrical Work of Girard Desargues.* Translated and edited by J. V. Field and J. J. Gray. New York: Springer, 1987, x + 237 pp.

A English translation of Desargues's *Brouillon project* (1639) together with the Greek legacy on which the project was built. There are elaborate footnotes, translations of lesser works on perspective, and a vocabulary of Desargues's idiosyncratic botanical terminology.

2120. Taton, René. *L'oeuvre mathématique de G. Desargues*. Paris: Presses Universitaires de France, 1951, 232 pp.

The book contains a biography of Desargues and provides the text of his work on projective geometry, *Brouillon project d'une atteinte aux evenèmens des rencontres du cone avec un plan*. See also item 3067.

Descartes, René

(1596–1650)

2121. Descartes, René. *Exercises pour les éléments des solides. Essai en complément d'Euclide*. Edited and translated by Pierre Costabel. Paris: Presses Universitaires de France, 1987, xix + 122 pp.

An annotated transcription and translation into French of Descartes's *Progymnasmata de solidorum elementis* by P. Costabel, with an extensive commentary covering Descartes, Euler, and polyhedra.

2122. Descartes, René. *Discurso del método, dióptrica, meteoros y geometría*. Edited and translated by Guillermo Quintás Alonso. Madrid: Alfaguara, 1981, 490 pp.

An annotated Spanish translation of Descartes's *Discours de la méthode* (1637) and its appendices *La dioptrique*, *Les meteores*, and the *Géométrie*.

2123. Bos, H. J. M. "On the Representation of Curves in Descartes's Géométrie". *Archive for History of Exact Sciences* 24 (1981), 295–338.

This is a study of the role of curves and constructions in the *Géométrie*. It is argued that a fundamental contradiction underlies the *Géométrie* and its program, namely, the contradiction between the usefulness of algebra as a tool in geometry and the need for truly geometrical criteria for adequacy of constructions. See also item 3031.

2124. Grosholz, Emily. *Cartesian Method and the Problem of Reduction*. Oxford: Clarendon Press, 1991, x + 161 pp.

An examination of the impact of Descartes's reductive scientific method, as exposed in his *Géométrie*, *Principia Philosophiae*, *Traité de l'homme* and *Meditationes*, on his scientific and philosophical thought.

2125. Hofmann, Joseph E. "Descartes und die Mathematik". In *Descartes. Drei Vorträge*. Edited by H. Scholz et al. Münster: Aschendorff, 1951, 48–73.

Short survey of Descartes's early mathematical studies and of the content of the *Géométrie*. Hofmann stresses the role of Descartes's interest in method.

2126. Milhaud, G. *Descartes savant*. Paris: Alcan, 1921, 249 pp.

In this collection of essays on Descartes's scientific work much attention is given to his mathematics. Particularly useful are Chapters I and III (pp. 25–46, 69–88) on Descartes's early mathematical studies, and Chapters VI and VII (pp. 124–175) on analytical geometry and infinitesimal methods.

2127. Scott, J. F. *The Scientific Work of René Descartes (1596–1650).* London: Taylor & Francis, [1952], vi + 211 pp. Reprinted 1976.

Chapters VI–IX, pp. 84–157, concern mathematics, in particular Descartes's *Géométrie* which is presented through paraphrase and occasional comments. See also item 3063.

2128. Vuillemin, J. *Mathématiques et métaphysique chez Descartes.* Paris: Presses Universitaires de France, 1960, iv + 188 pp.

Thought-provoking essays on themes from Descartes's mathematics (with considerable attention to transcendental relations and curves) and their metaphysical aspects. The arguments are often very speculative and the factual information cannot always be trusted.

Fabry, Honoré (1607–1688)

2129. Fellmann, Emil A. "Honoré Fabry (1607–1688) als Mathematiker—eine Reprise". In P. M. Harman, and Alan E. Shapiro eds. *The Investigation of Difficult Things.* (2183) 97–112.

The author takes up some items from his dissertation on Fabry, published in *Centaurus* 9 (1963/64), 139–193.

Faulhaber, Johannes (1580–1635)

2130. Schneider, Ivo. *Johannes Faulhaber 1580–1635. Rechenmeister in einer Welt des Umbruchs.* Basel, Boston, Berlin: Birkhäuser Verlag, 1993, xiv + 271 pp.

2131. Hawlitschek, Kurt. *Johann Faulhaber 1580–1635. Eine Blütezeit der mathematischen Wissenschaften in Ulm.* Ulm: Stadtbibliothek, 1995, xiv + 376 pp.

Two biographies of the reckonmaster and engineer Faulhaber whom Descartes is supposed to have met in Ulm in 1619/20. While Schneider (item 2130) remains sceptical and emphasizes the metaphorical importance as an encounter between two men representing different traditions, Hawlitschek's account profits from his intimate familiarity with the local circumstances in Ulm.

Fermat, Pierre (1601–1665)

2132. Cifoletti, Giovanna Cleonice. *La Méthode de Fermat: Son statut et son diffusion.* Paris: Belin, 1990–91, 243 pp.

Fermat's method for finding tangents and extreme values is analyzed. The variants of the formulation, the historical context, and the transformation during diffusion (Herigon, Huygens) are studied.

2133. Hofmann, Joseph E. "Pierre Fermat. Eine wissenschaftsgeschichtliche Skizze". *Scientiarum Historia* 13 (1971), 198–238.

A survey of Fermat's life and work, without technical details.

2134. Hofmann, Joseph E. "Pierre de Fermat—ein Pionier der neuen Mathematik († 12.1.1665)". *Praxis der Mathematik* 7 (1965), 113–119, 171–180, and 197–203.

A short biography of Fermat and comments on some of his studies in analytical geometry, number theory, and infinitesimal calculus.

2135. Itard, Jean. "Pierre Fermat". (Supplement No. 10 of the journal *Elemente der Mathematik*.) Basel: Birkhäuser, 1950, 24 pp. In French.

A short biography of Fermat and a survey of his main contributions to mathematics.

2136. Mahoney, Michael Sean. *The Mathematical Career of Pierre de Fermat (1601–1665).* Princeton, N.J.: Princeton University Press, 1973, xviii + 419 pp. 2nd edition, 1994, 438 pp.

The book gives a good picture of Fermat's contributions to mathematics. Fermat's role in the shift to use of coordinates in treating geometric problems and his role in the development of calculus is well described; however, because of the technical details, Mahoney's account is sometimes difficult to follow. See also item 3508.

Gregorie (Gregory), James (1638–1675)

2137. Malet, Antoni. *Studies on James Gregorie (1638–1675).* Ph.D. dissertation, Princeton University, 1989.

On the mathematical and optical work of James Gregorie (Gregory), in comparison with the contributions of Barrow and Newton. It is shown that David Gregory's *Geometria practica* as well as his optical book rely heavily on James's manuscripts.

2138. Scriba, C. J. *James Gregorys frühe Schriften zur Infinitesimalrechnung.* (Mitteilungen aus dem Mathematischen Seminar Giessen, Nr. 55.) Giessen: Selbstverlag des Mathematischen Seminars, 1957, 80 pp.

This study deals with J. Gregory's (often underestimated) merits in the development of the differential and integral calculus. It contains valuable surveys of the contents of Gregory's principal works and of some manuscripts and letters.

2139. Turnbull, Herbert Westren, ed. *James Gregory Tercentenary Memorial Volume. Containing His Correspondence with John Collins and His Hitherto Unpublished Mathematical Manuscripts, Together with*

Addresses and Essays Communicated to the Royal Society of Edinburgh, July 4, 1938. London: G. Bell & Sons, 1939, xii + 524 pp.

This volume consists mainly of an edition of Gregory's correspondence and his mathematical papers. A biographical sketch and short articles by several scholars on Gregory's published works are also included.

Harriot, Thomas (ca. 1560–1621)

2140. Lohne, J. A. "Thomas Harriot als Mathematiker". *Centaurus* 11 (1966), 19–45.

Deals with some of Harriot's studies of the loxodrome, areas of spherical triangles, interpolations, the law of refraction, and coordinates. See also item 3551.

2141. Lohne, J. A. "Essays on Thomas Harriot". *Archive for History of Exact Sciences* 20 (1979), 189–312.

The article consists of three parts: I. Billiard Balls and Laws of Collision. II. Ballistic Parabolas. III. A Survey of Harriot's Scientific Writings.

Heuraet, Hendrick van (1634–1660?)

2142. Van Maanen, Jan A. "Hendrick van Heuraet (1634–1660?): his life and mathematical work.". *Centaurus* 27(1984), 218–279.

On life and work of Hendrick van Heuraet and his relations with Sluse, Huygens, Schooten and Hudde. Among the topics discussed between these mathematicians were properties of curves and the rectification of the parabola.

Hudde, Johann (1628–1704)

2143. Haas, Karlheinz. "Die mathematischen Arbeiten von Johann Hudde (1628–1704), Bürgermeister von Amsterdam". *Centaurus* 4 (1955/1956), 235–284.

Contains a biography and a survey of Hudde's contributions to the theory of equations and the infinitesimal calculus.

Huygens, Christiaan (1629–1695?)

2144. Bell, A. E. *Christian Huygens and the Development of Science in the Seventeenth Century*. London: Arnold, 1947. Reprinted 1950, 220 pp.

Scientific biography of Huygens; there is no separate section on Huygens's mathematics.

2145. Bos, H. J. M., et al., eds. *Studies on Christiaan Huygens; Invited Papers from the Symposium on the Life and Work of Christiaan Huygens,* *Amsterdam, 22–25 August 1979.* Lisse: Swets & Zeitlinger, 1980, 321 pp.

The invited papers combine to form an overall scientific biography of Huygens. There is a paper on his mathematics (by H. J. M. Bos, pp. 126–146); papers on mechanics (by Alan Gabbey, pp. 166–199) and on the measurement of time and longitude at sea (by Michael S. Mahoney, pp. 234–270) are also informative about Huygens's use of mathematical methods.

2146. Dijksterhuis, E. J. "Christiaan Huygens; An Address Delivered at the Annual Meeting at the Holland Society of Sciences at Haarlem, May 13th, 1950, on the Occasion of the Completion of Huygens's Collected Works". *Centaurus* 2 (1951/1953), 265–282.

Short sketch of Huygens's life and work.

2147. Maanen1985 Van Maanen, Jan A. "Unknown Manuscript Material of Christiaan Huygens". *Historia Mathematica* 12 (1985), 60–65.

A description of four newly discovered unpublished manuscripts or collections of mathematical notes by Huygens.

2148. Vilain, Christiane. *La Mécanique de Christian Huygens. La relativité du mouvement au XVIIe siècle.* Paris: Albert Blanchard, 1996, viii + 287 pp.

Huygens built his mechanics on the twin foundations of Galilean relativity and the Cartesian laws of impact. The author shows how Huygens developed Galileo's insights and radically transformed Descartes's laws of motion. But most of Huygens's work in mechanics, based on geometrical thinking, was only published posthumously in 1703 and hence did not exert the influence it might otherwise have had.

2149. Yoder, Joella G. *Unrolling time: Christiaan Huygens and the mathematization of nature.* Cambridge: Cambridge University Press, 1988, xi + 238 pp.

A case study of the interrelationships between mathematics and physics in the work of Huygens. Themes dealt with include the pendulum clock, gravitational acceleration, centrifugal force, theory of evolutes. Also discussed are his relationship with other scientists, his work patterns, priority disputes, and his role in the rise of applied mathematics.

Junigius, Joachim (1587 –1657)

2150. Elsner, Bernd. *"Apollonius Saxonicus." Die Restitution eines verlorenen Werkes des Apollonius von Perga durch Joachim Jungius, Woldeck Weland und Johannes Müller (= Veröffentlichung der Joachim*

Jungius-Gesellschaft der Wissenschaften Nr. 57). Göttingen: Vandenhoek & Ruprecht, 1988, 430 pp.

Edition of a reconstruction of the two lost books about plane loci of Apollonius of Perga, made by Jungius, his pupil Woldeck Weland and the professor of mathematics Johannes Müller. The reconstruction was begun in 1622 while Jungius was professor of mathematics in Rostock, and continued by his pupil and his colleague at the Akademische Gymnasium in Hamburg. This first edition of the Latin text includes an introduction and a German translation by the editor.

2151. Hübner, Gaby. *Aus dem literarischen Nachlass von Joachim Jungius—Edition der Tragödie "Lucreatia" und der Schul- und Universitätsreden (= Veröffentlichung der Joachim Jungius-Gesellschaft der Wissenschaften Nr. 82).* Göttingen: Vandenhoek & Ruprecht, 1995, 336 pp.

The speeches given at official occasions by Jungius in his position as professor and (since 1629) rector of the Akademische Gymnasium und Johanneum in Hamburg very often emphasized the propedeutics of mathematics, drew on historical examples from classical Greek mathematics, or pointed towards achievements of the sciences of his time.

2152. Meinel, Christoph. *Der handschriftliche Nachlass von Joachim Jungius in der Staats- und Universitätsbibliothek Hamburg. Katalog.* Stuttgart: Hauswedell, 1984, xxxviii + 154 pp.

The vast collection of Jungius's papers in Hamburg, for which this book provides a modern catalogue, includes more than 5000 folios on mathematical topics. There is a detailed index of names and subjects.

2153. Meinel, Christoph. *Die Bibliothek des Joachim Jungius. Ein Beitrag zur Historia litteraria der frühen Neuzeit (= Veröffentlichung der Joachim Jungius-Gesellschaft der Wissenschaften Nr. 67).* Göttingen: Vandenhoek & Ruprecht, 1992, 224 pp.

A reconstruction of the highly specialized library of Jungius: 1175 titles in more than 1000 volumes could be identified on the basis of old catalogues, notes about purchase, etc. With a history of the collection, statistical information of the distribution among various disciplines (an unusually high percentage of titles comes from mathematics and the sciences), and observations on book collecting in early modern times.

Kepler, Johannes (1571–1630)

2154. Kepler, Johannes. *Gesammelte Werke. Band IX. Mathematische Schriften.* Edited by Franz Hammer. Munich: C. H. Beck, 1960.

The *Nachbericht* (pp. 427–483) is a detailed account of the content and origin of the *Stereometria*, the *Messekunst*, and Kepler's work on logarithms. See also item 2866.

2155. Kepler, Johannes. *De coni sectionibus. Über die Kegelschnitte. Lateinische und Deutsch.* Edited and translated by Thomas Dittert. Baunatal (Germany): Buchhandlung Thomas Dittert, 1990, 62 pp.

Two short extracts on conis sections from Kepler's *Ad Vitellionem paralipomena* (written 1604) and *Messekunst Archimedis* (1616), with 25 pp. of introduction and notes.

2156. Kepler, Johannes. *The Harmony of the World*. Philadelphia: American Philosophical Society, 1996, 600 pp.

A translation into English (with an introduction and notes by E. J. Aiton, A. M. Duncan, and J. V. Field) of Kepler's classical *Harmonices Mundi Libri V* first published in Linz in 1619. Book I deals with regular plain figures, which for Kepler were the sources of harmonic proportions, book II contains his investigations of regular, semi-regular and star-shaped polyhedra.

2157. Field, J. V. *Kepler's Geometrical Cosmology.* Chicago, IL: The University of Chicago Press, 1988, xx + 243 pp.

An examination of Kepler's attempts to explain the structure of the universe, as expounded in his *Mysterium cosmographicum* and his *Harmonices mundi libri V*, with emphasis on Kepler's geometrical models (regular figures, Platonic solids) and the influence of Platonism on his cosmology. Astronomy, geometry, music and theology are involved.

2158. Hofmann, Joseph E. "Ueber einige fachliche Beiträge Keplers zur Mathematik". *Internationales Kepler Symposium, Weil der Stadt*, 1971. Edited by F. Krafft et al. Hildesheim: Dr. H. A. Gerstenberg, 1973, 261–284.

Discusses Kepler's mathematical background, his study of polyhedra, and his solution of some quadrature problems.

2159. Hofmann, Joseph E. "Johannes Kepler als Mathematiker". *Praxis der Mathematik* 13 (1971), 287–293 and 318–324.

Treats the same topics as the article in item 2158 above and adds a short biography of Kepler.

2160. Rosen, Edward. *Three Imperial Mathematicians: Kepler Trapped between Tycho Brahe and Ursus.* New York: Abaris Books, 1986, 384 pp.

Detailed study of the controversial relationships between three successive Imperial Mathematicians of the Holy Roman Empire working at the court in Prague: Nikolaus Reimers, "Reimarus (Ursus)", Tycho Brahe, and Kepler.

2161. Stephenson, Bruce. *Kepler's Physical Astronomy.* Princeton: Princeton University Press; New York, N.Y.: Springer, 1987, vii + 217 pp. Reprinted 1994, (Paperback edition.)

The author seeks to elucidate the steps by which Kepler developed his planetary theory, by analyzing three books: Kepler's *Mysterium cosmographicum*, *Astronomia nova*, and *Epitome astronomiae Copernicanae*.

2162. Stephenson, Bruce. *The Music of the Heavens: Kepler's Harmonic Astronomy.* Princeton: Princeton University Press, 1987, xi + 260 pp. Reprinted 1994, (Paperback edition.)

First a survey of early theories on the relationship between music and astronomy (from the Pythagoreans to the Renaissance is given, then an analysis of Kepler's *Harmonices mundi* of 1619, including its prehistory, is presented. In particular detail book V is discussed which treats harmonies that according to Kepler govern the planetary motions. In his final chapter, the author summarizes the reception of Kepler's book by Jeremiah Horrocks, Giovanni Battista Riccioli, and Mario Bettini.

Leibniz, Gottfried Wilhelm (1646–1716)

2163. Leibniz, G. W. *De quadratura arithmetica circuli ellipseos et hyperbolae cujus corollarium est trigonometria sine tabulis. Kritisch herausgegeben und kommentiert von Eberhard Knobloch.* Edited by Eberhard Knobloch. Göttingen: Vandenhoeck & Ruprecht, 1993, 160 pp.

The first complete edition of a text written towards the end of his soujourn in Paris (around 1676), in which Leibniz developed a universal, demonstrative system of infinitesimal geometry: a theory of analytical curves, a foundation of the use of infinitesimal quantities in the analysis, and the application of infinite series to problems of quadratures. Only the main results are contained in the well-known publication by Leibniz in the *Acta eruditorum* of 1682.— In his edition, Knobloch, E. observed the detailed editorial rules of the monumental academy edition *Sämtliche Schriften und Briefe* of Leibniz.

2164. Leibniz, G. W. *La Réforme de la dynamique. De corporum concursu (1678) et autres textes inédits.* Edited by Michel Fichant. Paris: J. Vrin, 1994, 245 pp.

Edition, with introduction, commentary, and French translation by Michel Fichant, of published and unpublished texts by Leibniz, written in 1678—an important stage of the development of his ideas about dynamics between 1671 and 1686.

2165. Leibniz, G. W. *La Caratéristique géométrique.* Edited by Javier Echeverría. Paris: Librairie Philosophique J. Vrin, 1995, 367 pp.

Latin edition, with French translations by Marc Parmentier, of 18 manuscripts by Leibniz on the "calculus of situation" (analysis situs, geometria situs, characteristica situs—geometrical relationships without recourse to metric properties), with comments by Javier Echeverría.

2166. Aiton, E. J. *Leibniz. A biography.* Bristol/Boston: Adam Hilger, IOP Publishing, 1985, xiv + 370 pp.

2167. Meli1993 Bertoloni Meli, Domenico. *Equivalence and Priority: Newton versus Leibniz. Including Leibniz's unpublished manuscripts on the Principia.* Oxford: Clarendon Press, 1993, ix + 318 pp. Reprinted Oxford: Oxford University Press, 1997, ix + 318 pp. (Paperback edition.)

Based on a careful examination of manuscripts (edited in this volume with English translations and commentaries), the author demonstrates that Leibniz wrote his *Tentamen de Motuum Coelistium Causis* (published in 1689) as a reaction to Newton's *Philosophiae naturalis principia mathematica* of 1687. Leibniz rejected the conception of a void cosmos in which gravitation acts at a distance, in favour of a vortex theory. With his discussion of general themes (such as equivalence between rival theories and the role of controversies and priority claims in the 17th century) the author provides fresh insight into the Newton-Leibniz rivalry.

2168. Child, J. M. *The Early Mathematical Manuscripts of Leibniz Translated from the Latin Texts Published by Carl Immanuel Gerhardt with Critical and Historical Notes.* Chicago, London: Open Court Publishing Company, 1920, iv + 238 pp.

Useful in providing texts that are otherwise not easily accessible. But the commentaries to the texts, written from an interest in settling the priority and plagiarism dispute, are superseded by later research and should not be trusted.

2169. Hall, A. Rupert. *Philosophers at War. The Quarrel between Newton and Leibniz.* Cambridge: Cambridge University Press, 1980, xiii + 338 pp.

Hall accounts for the ingredients of the famous controversy about the priority of the creation of the calculus; and in non-technical language he describes the difference between Newton's and Leibniz's approaches to the calculus. Further, Hall discusses earlier writings about the quarrel and reaches very sensible conclusions.

2170. Hofmann, Joseph E. *Leibniz in Paris, 1672–1676, His Growth to Mathematical Maturity*. Cambridge: Cambridge University Press, 1974, xi + 372 pp.

This revised translation of Hofmann's *Die Entwicklungsgeschichte der Leibnizschen Mathematik während des Aufenthaltes in Paris (1672–1676)*, Munich, 1949, minutely traces Leibniz's studies leading up to his "invention of the calculus" in 1675. It aims at finally setting right many conflicting statements of historians and others about Leibniz's achievements, a very sensitive matter because of the priority and plagiarism dispute between Leibniz and Newton. Hofmann concludes that, as to the methods of the infinitesimal calculus, Leibniz "wholly uninfluenced by others, gained his crucial insights unaided" (p. 306).

2171. Knobloch, E., ed. *Die mathematischen Studien von G. W. Leibniz zur Kombinatorik*. (Studia Leibnitiana Supplementa, Band XI.) Wiesbaden: Franz Steiner Verlag, 1973, xvi + 277 pp.

2172. Knobloch, E., ed. *Die mathematischen Studien von G. W. Leibniz zur Kombinatorik. Textband*. (Studia Leibnitiana Supplementa, Band XVI.) Wiesbaden: Franz Steiner Verlag, 1976, xii + 339 pp.

The former volume is a detailed monograph based mostly on manuscript material. Its main topics are Leibniz's "Dissertatio de arte combinatoria", symmetric functions, and the theory of partitions. The second volume contains an edition of 60 manuscripts—the most important ones of those that are analyzed in the former volume. See also item 3443.

2173. Knobloch, E., ed. *Der Beginn der Determinantentheorie. Leibnizens nachgelassene Studien zum Determinantenkalkül. Textband. (Arbor Scientiarum, Reihe B. Bd. II.)*. Hildesheim: Gerstenberg, 1980, 332 pp.

Publication of 66 manuscripts by Leibniz on determinants. The studies deal with systems of linear equations, general equations in several variables of higher degrees and related topics. The volume supplements the edition in item 2172.

2174. Zacher, Hans J. *Die Hauptschriften zur Dyadik von G. W. Leibniz. Ein Beitrag zur Geschichte des binären Zahlensystems*. Frankfurt am Main: Vittorio Klostermann, 1973, viii + 384 pp.

This monograph traces in detail the development of Leibniz's ideas about the binary system and the importance he assigned to it in his philosophical views. In an appendix (pp. 216–356) 28 important letters or manuscripts on the subject are published in a critical edition.

Mengoli, Pietro (1625–1686)

2175. Mengoli, Pietro. Edited by G. G. Baroncini, and M. Cavazza. *La corrispondenza di Pietro Mengoli.* Florence: Leo S. Olschki, 1986,

Napier, John (1550–1617)

2176. Napier, John. Translated by William Frank Richardson. *Rabdology.* Cambridge, MA: MIT Press, 1990, xxxvii + 135 pp.

First complete translation from Latin to English of Napier's *Rabdologia* of 1617, including a guide to "Napier's bones."

2177. Gridgeman, N. T. "John Napier and the History of Logarithms". *Scripta Mathematica* XXIX (1973), 49–65.

An easily read survey of Napier's life and his logarithms.

2178. Knott, C. G., ed. *Napier Tercentenary Memorial Volume.* London, New York, Bombay, Calcutta and Madras: Longmans, Green and Company. 1915, ix + 441 pp.

The first seven articles (pp. 1–137) deal with Napier and the development of logarithms and the law of exponents.

Newton, Sir Isaac (1642-1727)

2179. Newton, Isaac. *Optica o tratado de las reflexiones, refracciones, inflexiones y colores de la luz.* Edited and translated by Carlos Solis. Madrid: Alfaguara, 1977, 454 pp.

Spanish translation of Newton's *Opticks*, not including the *Tractatus de quadratura curvarum.* With introduction, extensive bibliography, and analytic index.

2180. Newton, Isaac. *Principios mathemáticos de la filosofía natural.* Edited and translated by Antonio Escohotoda. Madrid: Editora Nacional, 1982, 908 pp.

First Spanish translation of Newton's *Philosophiae naturalis principia mathematica*, with extensive introduction notes.

2181. Gjertsen, Derek. *The Newton Handbook.* London, New York: Routledge & Kegan Paul, 1986, xiv + 665 pp.

Summaries of uneven quality of more than four hundred widely differing Newton items. These focus on his life and writings, but include scientific terms, predecessors, contemporaries, followers, and historians of science as well. There is a 15-page bibliography and a 25-page list of entries and index.

2182. Hall, A. Rupert. *Isaac Newton. Adventurer in Thought.* Oxford: Blackwell Publishers, 1992, xvi + 468 pp.

A scholarly biography, written with fine sympathetic understanding. It not only covers Newton's many-sided activities but also indicates the difficulties the historian faces in adequately interpreting his source material. The author avoids, however, confronting the reader with detailed mathematics.

2183. Harman, P. M., and Alan E. Shapiro, eds. *The Investigation of Difficult Things: Essays on Newton and the history of the exact sciences in honour of D. T. Whiteside*. Cambridge: Cambridge University Press, 1992, xvi + 531 pp.

A collection of 20 essays centering on Newton's mathematics, astronomy, dynamics, optics, and its influences, in honour of the editor of *The Mathematical Papers of Isaac Newton*. Included is a bibliography of D. T. Whiteside's publications.

2184. Hofmann, Joseph E. "Der junge Newton als Mathematiker (1665–1675)". *Mathematisch-physikalische Semesterberichte* 2 (1951/1952), 45–70.

D. T. Whiteside's valuable work on Newton, items 2189–2192, has provided us with much more information than Hofmann had when writing this article; still, it contains useful comments on Newton's mathematics.

2185. Schneider, Ivo. *Isaac Newton*. München: C. H. Beck, 1988, 194 pp.

A pocket book Newton biography in German, based on Westfall's *Never at Rest* (item 2187) and making full use of the results of modern research on Newton's papers.

2186. Scriba, Christoph J. "The Inverse Method of Tangents: A Dialogue Between Leibniz and Newton (1675–1677)". *Archive for History of Exact Sciences* 2 (1962–1966), 113–137.

See item 2795.

2187. Westfall, Richard S. *Never at Rest. A Biography of Isaac Newton*. Cambridge: Cambridge University Press, 1980, xviii + 908 pp.

A comprehensive scientific biography including descriptions of Newton's mathematical discoveries. See items 2824, 2188.

2188. Westfall, Richard S. *The Life of Isaac Newton*. Cambridge: Cambridge University Press, 1993, xxii + 328 pp.

A condensed version of the author's monumental Newton biography *Never at Rest*, item 2187 (many technical and mathematical details, as well as the footnotes, are omitted, but the organization of the material parallel to the original work allows the reader to check the references if need be).

2189. Whiteside, D. T. "Isaac Newton: Birth of a Mathematician". *Notes and Records of the Royal Society of London* 19 (1964), 53–62.

Describes Newton's mathematical training up to 1664.

2190. Whiteside, D. T. “Newton’s Marvellous Year: 1666 and All That”. *Notes and Records of the Royal Society of London* 21 (1966), 32–41.

A non-technical description of Newton’s mathematical achievements in the period 1664–1666.

2191. Whiteside, D. T., ed. *The Mathematical Works of Isaac Newton*. New York and London: Johnson Reprint Corporation, 1964–1967. 2 vols.

The introductions (vol. I, pp. vii–xix, and vol. II, pp. ix–xxvii) provide a concise summary of Newton’s mathematical development. Unlike Horsley’s edition of the *Opera*, this reprint contains those works that have been published in English.

2192. Whiteside, D. T., ed. *The Mathematical Papers of Isaac Newton*. Cambridge: Cambridge University Press, 1967–1981. 8 vols.

The introductions in the eight volumes give a survey of Newton’s mathematical research. Exceptionally valuable are the notes provided by Whiteside throughout the eight volumes, offering a penetrating analysis of Newton’s historical development as a mathematician.

Pascal, Blaise (1623–1662)

2193. Bosmans, H. “Sur l’oeuvre mathématique de Blaise Pascal”. *Mathesis* 38 (1924), Supplement. Also Extrait de la *Revue des Questions scientifiques* (January and April 1924), 1–59, separately paginated.

Leisurely written survey of Pascal’s mathematical works, composed in order to assess Pascal’s merits as compared with other 17th-century mathematicians.

2194. Dariulat, Jacques. *L’arithmétique de las Grace: Pascal et les carrés magiques*. Paris: Les Belles Lettres, 1994, 147 pp.

An account of Pascal’s work on magic squares.

2195. Edwards, A. W. F. *Pascal’s arithmetical triangle*. London: Griffin, and New York: Oxford University Press, 1987, xii + 174 pp.

The book traces the frequent occurrences of “Pascal’s” arithmetical triangle in Pythagorean arithmetic, Hindu combinatorics, and Arabic algebra, and analyzes Pascal’s work. Interpretations by Wallis, Newton, and Nicolaus Bernoulli are also considered. Emphasis is given more to the mathematics than to the presentation of a connected history of the underlying ideas.

2196. Loeffel, Hans. *Blaise Pascal, (1623–1662). (Vita Mathematica, Bd. 2).* Basel, Boston, Stuttgart: Birkhäuser Verlag, 1987, 176 pp.

This biography in German centers on Pascal the mathematician, explaining examples of the mathematical problems he investigated by using modern notation. Topics include projective geometry, arithmetic triangle, probability theory, infitesimal calculations, and the calculating machine.

2197. Schobinger, Jean-Pierre. *Blaise Pascals Reflexionen über die Geometrie im allgemeinen: "De l'esprit géométrique" und "De l'art de persuader.* Mit deutscher Übersetzung und Kommentar. Basel, Stuttgart: Schwabe & Co., 1974, 522 pp.

This scholarly edition contains a brief curriculum vitae of Pascal, 70 pages of French text with German translation of the two papers, approximately 350 pages of commentary and 50 pages of critical apparatus.

2198. Taton, René, ed. *L'oeuvre scientifique de Pascal.* Paris: Presses Universitaires, 1964, ix + 311 pp.

Most of the fourteen chapters of the book are devoted to Pascal's mathematical work, particularly on projective geometry, mathematical induction, infinitesimal calculus, and the calculating machine.

Ricci, Michel Angelo (1619–1682)

2199. Hofmann, Joseph Ehrenfried. "Über die Exerciatio geometrica des M. A. Ricci". *Centaurus* 9 (1963/64), 139–193.

The paper concentrates on the *Exercitatio geometrica* (published in Rome, 1666, reprinted in London, 1668), in which Ricci determined tangents to "higher conic sections." In addition, his quadrature of the cissoid and his correspondence with Torricelli are discussed.

Roberval, Gilles Personne de (1602–1675)

2200. Auger, Léon. *Un savant méconnu: Gilles Personne de Roberval (1602–1675).* Paris: Blanchard, 1962, 215 pp.

The book contains a short biography of Roberval, deals with his contributions to the infinitesimal calculus, and further discusses his work in mechanics and philosophy.

2201. Pedersen, Kirsti Møller. "Roberval's Method of Tangents". *Centaurus* 13 (1968), 151–182.

Covers Roberval's kinematic method of tangents and its place in the history of kinematic arguments in the development of the infinitesimal calculus.

2202. Walker, Evelyn. *A Study of the Traité des indivisibles of Gilles Personne de Roberval.* New York: Teachers College, Columbia University, 1932, 273 pp.

Roberval's work on indivisibles is related to his other activities in mathematics and to the contributions of his contemporaries.

Roomen, Adriaan van (1561–1615)

2203. Bockstaele, Paul, ed. "The Correspondence of Adriaan van Roomen (1561–1615)". *Lias* 3 (1976), 85–129, 249–299.

2204. Bockstaele, Paul, ed. "The Correspondence of Adriaan van Roomen (1561–1615): Corrections and additions, 1594–1615." *Lias* 19 (1992), 3-20.

While the earlier edition contained 41 letters, seven more are edited here in the original Latin.

Van Schooten, Frans (1615–1660)

2205. Hofmann, Joseph Ehrenfried. *Frans van Schooten der Jüngere.* Wiesbaden: F. Steiner Verlag, 1962, viii + 54 pp.

On the editor of the mathematical works of F. Viète and R. Descartes and his own mathematical writings, with detailed documentation of the sources.

de Sluse, René François (1622–1685)

2206. Halleux, Robert, ed. "René François de Sluse (1622–1685). Actes du Colloque International Amay–Liège–Vise, 20–22 mars 1985". *Bulletin de la Société Royale des Sciences de Liège, 55e anneé* 1 (1986), 1–269.

Papers given at the colloquium devoted to Sluse. Authors of papers dealing with mathematics are P. Bockstaele, H. J. M. Bos, A. Brigaglia, P. Butzer, E. Knobloch and R. Taton

2207. Jongmans, François, Robert Halleux, Pascal Lefebvre, and Anne-Catherine Bernes, eds. *Les Sluse et leur temps. Une famille, une ville, un savant au XVII*e *siécle.* Liège: Credit Communal, 1985, 112 pp.

An exhibition catalogue. Pp. 47–109 deal with life and work of R. F. de Sluse and his relations to contemporary mathematicians and scientists.

2208. Le Paige, C. "Correspondance de René-François de Sluse publiée pour la première fois et précédée d'une introduction par Le Paige". *Bullettino di bibliografia e di storia delle scienze matematiche e fisiche* 17 (1884). Reprinted New York & London: Johnson Reprint Corporation, 1964, 427–554, 603–726.

The first 75 pages of this edition contain a biography of Sluse and a survey of his mathematical work.

Stevin, Simon (1548–1620)

2209. Dijksterhuis, E. J. *Simon Stevin. Science in the Netherlands around 1600.* The Hague: Nijhoff, 1970, ix + 145 pp.

This is a very condensed English edition of Dijksterhuis's very thorough and detailed Dutch monograph *Simon Stevin* (The Hague: Nijhoff, 1943, xii + 379 pp.). Dijksterhuis himself started the English edition; after his death R. Hooykaas and M. G. J. Minnaert completed and edited it. There is a separate chapter on Stevin's mathematics, pp. 14–47.

2210. Struik, D. J., ed. *The Principal Works of Simon Stevin. Vol. II A and B.* Amsterdam: Swets & Zeitlinger, 1958, 976 pp.

In the introductions to Stevin's various mathematical works, Struik very usefully sets these in a historical perspective.

Torricelli, Evangelista (1608–1647)

2211. *Opere di Evangelista Torricelli.* Edited by Loria, G., and G. Vassura. Vol. I–III. Faenza: Montanari, 1919; Vol. IV, Faenza: Lega, 1944.

The *Introduzione*, Vol. I, pp. iii–xxx, gives biographic and bibliographic information about Torricelli.

2212. De Gandt, François, ed. *L'Œuvre de Torricelli: Science Galiléenne et nouvelle géométrie.* Paris: Les Belles Lettres, 1987, 247 pp.

A collection of seven papers. Aspects involving the mathematical work of Torricelli, and his influence, are discussed by Michel Blay, François De Gandt, and E. Bortolotti (French translation of an article in Italian). A number of documents are also included.

2213. Weis, F. "Evangelista Torricelli". *Archiv für Geschichte der Mathematik, der Naturwissenschaften und der Technik, Neue Folge 1*, 10 (1927/1928), 250–281.

Contains a biography of Torricelli and an account of the history of his posthumous papers.

Wallis, John (1616–1703)

2214. Kramar, F. D. "Integrationsmethoden von John Wallis". *Istoriko-Matematicheskie Issledovaniia* 14 (1961), 11–100. In Russian.

This detailed study concentrates on Wallis's pre-calculus methods for integration, as presented first in *Arithmetica Infinitorum* of 1656/1657 with its famous result, the infinite product for $\pi/4$.

2215. Prag, A. "John Wallis, 1616–1703. Zur Ideengeschichte der Mathematik im 17. Jahrhundert". *Quellen und Studien zur Geschichte der Mathematik, Abt. B: Studien* 1 (1929), 381–412.

This study of Wallis's work, especially of the *Arithmetica Infinitorum* and the *Algebra*, is a valuable assessment of Wallis's achievements as compared with those of other 17th-century mathematicians.

2216. Scott, J. F. *The Mathematical Work of John Wallis, D.D., F.R.S. (1616–1703).* London: Taylor & Francis 1938, xi + 240 pp. Reprinted New York: Chelsea Publ. Co., 1981.

This book consists mainly of summaries of Wallis's principal mathematical works. There are also two short biographical chapters. As in his book on Descartes, Scott presents the contents of Wallis's mathematical publications mostly through paraphrase, enriched by occasional comments and set within the framework of Wallis's academic life.

2217. Scriba, C. J. *Studien zur Mathematik des John Wallis (1616–1703); Winkelteilunge, Kombinationslehre und zahlentheoretische Probleme. Im Anhang die Bücher und Handschriften von Wallis.* Wiesbaden: Steiner, 1966, xi + 144 pp.

In this study of a number of themes in Wallis's mathematical work, Scriba has made use of many hitherto unpublished manuscripts and letters of Wallis.

MATHEMATICS IN THE 18TH CENTURY

From the eighteenth century to the nineteenth we see the formation of distinct branches of mathematics and the transition from scattered practitioners to a profession with specialists. Thus most historical studies for the eighteenth through the twentieth centuries are best classified either under the various sub-disciplines of mathematics or under the various sub-divisions that historical studies themselves experienced and that reflect, for example, sociological, institutional, educational, and philosophical aspects treated from a historical point of view.

General Works and Special Studies

2218. Cajori, Florian. "Frederick the Great on Mathematics and Mathematicians". *American Mathematical Monthly* 34 (1927), 122–130.

2219. Gillispie, Charles Coulston. *The Edge of Objectivity: An Essay in the History of Scientific Ideas.* Princeton: Princeton University Press, 1960, 562 pp. Reprinted Princeton, New Jersey: Princeton University Press, 1990, 1988, xxvi + 562 pp. First printing with the new preface.

A good, general introduction to the 18th century in a chapter devoted to "Science and the Enlightenment". See also item 2952.

2220. Goldstine, Herman H. *A History of Numerical Analysis from the 16th through the 19th Century.* (Studies in the History of Mathematics and Physical Sciences, Vol. 2.) New York, Heidelberg, Berlin: Springer-Verlag, 1977, xiv + 348 pp., especially pp. 119–260.

Provides a survey of 18th-century developments and contends that the work of Euler and Lagrange must be considered the foundation of numerical analysis. Gives an account of the contributions of Euler, Lagrange, Laplace, Legendre, and Gauss. See also item 3516.

2221. Goldstine, Herman H. *A History of the Calculus of Variations from the 17th through the 19th Century.* (Studies in the History of Mathematics and Physical Sciences, Vol. 5.) New York, Heidelberg, Berlin: Springer, 1980, xviii + 410 pp., especially pp. 50–150.

Is the only recent account of the history of the calculus of variations; devotes about 100 pages to 18th-century developments.

2222. Greenberg, John. *The Problem of the Earth's Shape from Newton to Clairaut.* Cambridge, New York: Cambridge University Press, 1995, xviii + 781 pp.

A masterly account of the mathematics and scientific intrigues behind the great 18th century problem of the earth's shape. The main players are: Alexis-Claude Clairaut, A. Fontaine, Pierre Bouguer, Colin Maclaurin, Leonhard Euler, and J. D'Alembert. Reviewed by Lewis, Albert C. in *Historia Mathematica* 25 (1998), 320–325.

2223. Hofmann, Joseph E. *Classical Mathematics. A Concise History of the Classical Era in Mathematics.* Translated by H. O. Midonick. New York: Philosophical Library, 1959.

Chapter III is devoted to "Age of Enlightenment", pp. 115–154. Especially noteworthy is Chapter II, "The Late Baroque Period" (ca. 1665–1730), including discussion of infinitesimal mathematics in Japan, from 1650 to 1770 (pp. 101–114).

2224. Hofmann, Joseph E. "Um Eulers erste Reihenstudien". *Sammelband der zu Ehren des 250. Geburtstages Leonhard Eulers der Deutschen Akademie der Wissenschaften zu Berlin vorgelegten Abhandlungen.* Edited by K. Schröder. Berlin: Akademie Verlag, 1959, 139–208.

Provides a detailed chronology of the work on summation of series by the Bernoullis, Goldbach, Euler, and Stirling up to 1738. Contends that Euler's later contributions to the theory of series are a consolidation of the results arrived at in the period 1728–1738.

2225. Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972. Reprinted New York: Oxford University Press, 1990.

For the 18th century, chapters devoted to specific subjects include 18, "Mathematics as of 1700," pp. 391–399; 19, "Calculus in the Eighteenth Century," pp. 400–435; 20, "Infinite Series," pp. 436–467; 21, "Ordinary Differential Equations in the Eighteenth Century," pp. 468–501; 22, "Partial Differential Equations in the 18th Century," pp. 502–543; 23, "Analytic and Differential Geometry in the Eighteenth Century," pp. 544–572; 24, "The Calculus of Variations in the Eighteenth Century," pp. 573–591; 25, "Algebra in the 18th Century," pp. 592–613; and 26, "Mathematics as of 1800" begins on page 614. See also items 902, 2300, 2345, 2720, 3029, 3812.

2226. Montucla, J. F. *Histoire des mathématiques.* Nouv. ed. Paris: Henri Agasse, 1799–1802, vii + 739 + 718 + viii + 832 + 688 pp. 4 vols. Volumes 3 and 4 were edited by J. de la Lande. Photomechanically reprinted, with an introduction by Ch. Naux, Paris: Albert Blanchard, 1968.

Volumes 3 and 4 of this monumental treatise are devoted almost exclusively to the history of 18th-century mathematics. "Mathematics" is taken in its wide 18th-century denomination and includes calculus, optics, mechanics, machine building, astronomy, navigation, etc. The book provides a very valuable description of the state of the art in these subjects as seen through an educated contemporary eye.

2227. Nielsen, N. *Géomètres français du XVIIIème siècle.* Copenhagen, Paris: Levin & Munksgaard, 1935, 437 pp.

Published posthumously and arranged alphabetically.

2228. Scott, J. F. "Mathematics Through the Eighteenth Century". *Philosophical Magazine* (1948), 67–90.

Emphasis is placed on mathematics in England.

2229. Woodhouse, R. *A History of the Calculus of Variations in the Eighteenth Century*. Bronx, N.Y.: Chelsea Publishing Company, 1964.

This book is an unaltered reprint of *A Treatise of Isoperimetrical Problems and the Calculus of Variations* (Cambridge, 1810). Originally intended as a summary of 18th-century Continental developments in the calculus of variations in order to update the knowledge of British mathematicians, this book still serves as a very readable and uniform account of this field.

Studies of Individual Mathematicians

Bayes, Thomas (1702–1761)

2230. Bayes, T. *Facsimile of Two Papers, with Commentaries by E. C. Molina and W. E. Deming*. Washington, D.C.: The Graduate School, Department of Agriculture, 1940.

2231. Barnard, G. A. "Thomas Bayes, A Biographical Note" as a preface to T. Bayes, "An Essay Towards Solving a Problem in the Doctrine of Chances". *Biometrika* 45 (1958), 296–315.

2232. Savage, L. J. *The Foundations of Statistics*. New York: Wiley, 1954. 2nd rev. ed., New York: Dover, 1972.

Includes a very brief, explicitly historical "background" as part of the book's introduction on pages 1–4. Stresses foundational issues, aspects of the philosophical connections, and applications of statistics.

Bernoulli family

For general studies of the family, easily the most remarkable in the history of mathematics for the number and significance of its members from one generation to another, see the following.

2233. Fleckenstein, J. O. *L'école mathématique baloise des Bernoulli à l'aube du XVIIIe siècle*. Paris: Libraire de Palais de la Découverte, 1959.

2234. Spiess, O. "Die Mathematikerfamilie Bernoulli". In *Grosse Schweizer*. Edited by Huerlimann. Zürich: Atlantis Verlag, 1942, 112–119.

2235. Spiess, O. "Bernoulli, Basler Gelehrtenfamilie". In *Neue deutsche Biographie*. Berlin: Duncker & Humblot, 1955, 128–131.

Bernoulli, Daniel (1700–1782)

2236. Wolf, R. "Daniel Bernoulli von Basel, 1700–1782". In *Biographien zur Kulturgeschichte der Schweiz*. Zürich, 1860, 151–202.

Bernoulli, Jakob (Jacques) I (1654–1705)

2237. Fleckenstein, J. O. *Johann und Jakob Bernoulli. Elemente der Mathematik.* Basel: Birkhäuser, 1949, 24 pp.

See item 2111.

2238. Hofmann, Joseph E. *Über Jakob Bernoullis Beiträge zur Infinitesimalmathematik.* (Monographies de l'enseignement mathématique, No. 3.) Geneva: Institut de Mathématique, Université, 1956, 126 pp.

See item 2112.

Bernoulli, Johann (Jean) I (1667–1748)

2239. Hofmann, Joseph E. "Johann Bernoulli, Propagator der Infinitesimalmethoden". *Praxis der Mathematik* 9 (1967/1968), 209–212.

Carnot, Lazare-Nicolas-Marguerite (1753–1823)

2240. Boyer, Carl B. "The Great Carnot". *The Mathematics Teacher* 49 (1956), 7–14.

2241. Watson, S. J. *Carnot.* London: Bodley Head, 1954.

2242. Youschkevitch, Adolf P. "Lazare Carnot and the Competition of the Berlin Academy in 1786 on the Mathematical Theory of the Infinite". In *Lazare Carnot Savant.* Edited by C. C. Gillispie. Princeton: Princeton University Press, 1971, 149–168.

Includes as an appendix a photoreproduction of Carnot's "Dissertation sur la théorie de l'infini mathématique" with notes by A. P. Youschkevitch

.

Clairaut, Alexis-Claude (1713–1765)

2243. Brunet, P. *La vie et l'oeuvre de Clairaut.* Paris: Presses Universitaires de France, 1952.

Condorcet, Marie-Jean-Antoine, Marquis de (1743–1794)

2244. Granger, G.-G. *La mathématique sociale du Marquis de Condorcet.* Paris: Presses Universitaires de France, 1956.

2245. Taton, René. "Condorcet et Sylvestre-François Lacroix". *Revue d'histoire des sciences* 12 (1959), 127–158, 243–262.

D'Alembert, Jean le Rond (1717–1783)

2246. Grimsley, R. *Jean d'Alembert.* Oxford: Clarendon Press, 1963.

2247. Hankins, Thomas. *Jean d'Alembert. Science and the Enlightenment.* Oxford: Clarendon Press, 1970. Reprinted New York: Gordon and Breach, 1990.

See item 2686.

2248. Vollgraff, J. A. "Christian Huygens et Jean le Rond d'Alembert". *Janus* 20 (1915), 269–331.

Discusses the historical development of d'Alembert's principle.

De Moivre, Abraham (1667–1754)

2249. Schneider, Ivo. "Der Mathematiker Abraham de Moivre (1667–1754)". *Archive for History of Exact Sciences* 5 (1968–1969), 177–317.

An exhaustive account of the life and mathematical work of de Moivre, providing full bibliographic data (including unpublished materials). De Moivre was active in three fields: the theory of equations, to which he contributed trigonometric expressions for the roots of unity; series and recurrent expressions; and the theory of probability, containing de Moivre's derivation of the limit theorem for binomial distributions. See also item 3687.

2250. Walker, H. M. "Abraham de Moivre". *Scripta Mathematica* 2 (1934), 316–333.

Diderot, Denis (1713–1784)

2251. Krakeur, L. G., and R. L. Krueger. "The Mathematical Writings of Diderot". *Isis* 33 (1941), 219–232.

Euler, Leonhard (1707–1783)

2252. Carathéodory, C. "Introduction to Euler". *Opera omnia*, 24. Zurich: Orell Füssli, 1952.

Introductions to various individual volumes of Euler's *Collected Works* provide useful historical and critical surveys. Other useful commentaries include G. Faber on infinite series, 16 (1) (1935); G. Faber and A. Krazer on integrals, 19 (1) (1932); J. O. Fleckenstein on mechanics, 5 (2) (1957); A. Speiser on geometry, 26–29 (1) (1953–1956); and C. Truesdell, "The Rational Mechanics of Flexible or Elastic Bodies, 1630–1780", item 3260.

2253. Du Pasquier, L. G. *Leonhard Euler et ses amis.* Paris: J. Hermann, 1927.

2254. Eneström, G. "Verzeichnis der Schriften Leonhard Eulers". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 4 (1910–1913).

In three parts; Part I (organized by date of publication) is reprinted in Euler's *Opera Omnia*, 35, Part I, 352–386. Parts II and III are arranged in order of dates of composition and by subject, respectively.

2255. Spiess, O. *Leonhard Euler.* Frauenfeld, Leipzig: Huber & Co., 1929.

Among special collections of papers and commemorative issues, the most useful include the following.

2256. *Leonhard Euler 1701–1783: Beiträge zu Leben und Werk: Gedenkband des Kantons Basel-Stadt*. Edited by Fellman, E. A.. Basel, Boston, Stuttgart: Birkhäuser Verlag, 1983.

A handsomely produced commemorative volume giving a comprehensive picture of current Euler scholarship. Articles in English, French, but mostly German.

2257. *Festschrift zur Feier 200. Geburtstages Leonhard Euler*. Leipzig, Berlin: B. G. Teubner, 1907.

Contains numerous articles on Euler published by the Berliner Mathematische Gesellschaft.

2258. Deborin, A. M., ed. *Leonard Eyler, 1707–1783*. Moscow, Leningrad: n.p., 1935. Leonard Euler. In Russian.

2259. Lavrentiev, M. A., A. P. Youschkevitch, and A. T. Grigorian, eds. *Leonard Eyler, Sbornik statey*. Moscow: Akademiia Nauk SSSR, 1958.

2260. Schröder, K., ed. *Sammelband der zu Ehren des 200. Geburtstages Leonhard Eulers*. Berlin: Deutschen Akademie der Wissenschaften zu Berlin, 1959

See items 2224, 2831, and 3472.

2261. Winter, E., et al., eds. *Die deutsch-russische Begegnung und Leonhard Euler*. Berlin: Akademie-Verlag, 1958.

Hermann, Jacob (1678–1733)

2262. Nagel, Fritz. "A Catalogue of the Works of Jacob Hermann (1678–1733)". *Historia Mathematica* 18 (1991), 36–54.

Lagrange, Joseph Louis (1736–1813)

2263. Sarton, George. "Lagrange's Personality (1736–1813)". *Proceedings of the American Philosophical Society* 88 (1944), 457–496.

2264. Sarton, George, R. Taton, and G. Beaujouan. "Documents nouveaux concernant Lagrange". *Revue d'histoire des sciences* 3 (1950), 110–132.

2265. *J. L. Lagrange, Sbornik statey k 200–letiyu so dnya rozhdenia*. Moscow: Soviet Academy of Sciences, 1937.

Articles celebrating the second centenary of Lagrange's birth. Contents listed in *Isis* 28 (1938), 199.

Lambert, Johann Heinrich (1728–1777)

2266. Peters, W. S. "Lamberts Konzeption einer Geometrie auf einer imaginären Kugel". *Kantstudien* 53 (1961–1962), 51–67.

Based on the author's dissertation, University of Bonn, 1961.

2267. Steck, M. *Bibliographia Lambertiana*. Berlin: G. Lüttke, 1943. Rev. ed., Hildesheim: H. A. Gerstenberg, 1970.

Contains Lichtenberg's biography, as well as Lambert's bibliography in chronological order and a partial bibliography of secondary literature on Lambert.

2268. Speiser, A. "[Preface on Lambert]". In J. H. Lambert. *Opera Mathematica*. Edited by A. Speiser. Berlin, 1946; Zurich: Orell Füssli Verlag, 1948. 2 vols.

With a frontispiece engraving of Lambert. Both volumes contain the "Vorrede des Herausgebers", pp. ix–xxxi. Volume I also contains the "Éloge de M. Lambert", pp. 1–15, by J. H. S. Formey, reprinted from the *Nouveaux mémoires de l'Académie des sciences de Berlin (année 1778)*, Histoire (1780), pp. 72–91.

Laplace, Pierre-Simon, Marquis de (1749–1827)

2269. Andoyer, H. *L'oeuvre scientifique du Laplace*. Paris: Payot & Cie., 1922.

A short (192 pp.) but general introduction.

2270. Petrova, S. S. "K istorii metoda kaskadov Laplasa". *Istoriko-Matematicheskie Issledovaniia* 19 (1974), 125–131.

The article deals with Laplace's method of cascades.

2271. Petrova, S. S. "Rannyaya istoria preobrazovania Laplasa". *Istoriko-Matematicheskie Issledovaniia* 20 (1975), 246–256.

On the early history of the Laplace Transform.

2272. Sheynin, O. B. "O poyavlenii delta-funktsii Diraka v trudakh P. S. Laplasa". *Istoriko-Matematicheskie Issledovaniia* 20 (1975), 303–308.

On the appearance of Dirac's delta function in Laplace's work.

Maclaurin, Colin (1698–1746)

2273. Turnbull, H. W. "Colin Maclaurin". *American Mathematical Monthly* 54 (1947), 318–322.

2274. Turnbull, H. W. *Bicentenary of the Death of Colin Maclaurin*. Aberdeen: University Press, 1951.

Maupertuis, Pierre Louis Moreau de (1698–1759)

2275. Brunet, P. *Maupertuis*. Paris: Albert Blanchard, 1929. 2 vols.

Volume I: Etude Biographique.

Monge, Gaspard (1746–1818)

2276. Aubry, P.-V. *Monge, le savant ami de Napoléon: 1746–1818*. Paris: Gauthier-Villars, 1954.

2277. Taton, René. *L'oeuvre scientifique de Monge*. Paris: Presses Universitaires de France, 1951, 441 pp.

Discusses all aspects of Monge's work: descriptive, analytic, and synthetic geometry, and the geometric theory of partial differential equations. By embedding Monge's work in its historical context this book provides a fine survey of the development of geometry in the 18th century. See also items 2328, 3066.

Stirling, James (1692–1770)

2278. Tweedie, C. *James Stirling. Sketch of His Life and Works.* Oxford: Clarendon Press, 1922.

MATHEMATICS IN THE 19TH CENTURY

The nineteenth century was one of immense growth in mathematics. The best way into the period may be biographical, in which case the *Dictionary of Scientific Biography*, item 8, should be consulted, or, if the inquiry is topic-based, through the German *Encyklopädie*, item 5, also cited below in item 2283, or, for an overview, perhaps through the general histories of Klein, item 2299, and Kline, items 902.

Publications annotated here have been divided into several broad categories, including general reference works, journals especially useful for the history of mathematics in the nineteenth century, general histories and biographies of individual mathematicians. Within each group there has been a general attempt at classification, but the reader is advised to use pragmatic judgment in looking for items of interest.

Bibliographies

2279. Poggendorff, Johann Christian, ed. *Biographisch-literarisches Handwörterbuch zur Geschichte der exacten Wissenschaften*. Leipzig: J. A. Barth, 1863–1940. Reprinted Ann Arbor, Mich.: Edwards Bros., 1944. 6 vols.

Brief bibliographies of mathematicians and scientists. Volumes 1 and 2 cover through 1858. Under different editors, later volumes include materials available through 1931. Entries are of uneven lengths; emphasis is on bibliography rather than biography. This handy reference tool is especially strong on continental mathematicians. See also items 16, 17.

2280. *Royal Society of London. Catalogue of Scientific Papers*, 1800–1900. London: C. J. Clay, 1867–1902; volumes 13–19 have the imprint Cambridge: Cambridge University Press, 1914–1952. Reprinted New York: Johnson Reprint Corp., 1965. 19 vols.

Handy guide to periodical scientific literature of the 19th century. This valuable reference tool was inspired by Joseph Henry's suggestion that the British Association for the Advancement of Science sponsor a limited catalogue of contemporary scientific articles. It appeared in four series: first series (volumes 1–6), covering scientific literature published in article form during the period 1800–1863; second series (volumes 7–8), covering 1864–1873; third series (volumes 9–11), 1874–1883; and fourth series (volumes 13–19), 1884–1900. The first series contained references to all scientific articles appearing in the over 1,000 journals enumerated at the front of volume 1; with the second series the *Catalogue* was broadened to include inaugural addresses, biographies, and articles on the history of science. Volume 12 was a supplement which listed significant papers omitted from the preceding volumes because of publication in journals not previously indexed. All entries are arranged alphabetically according to authors; multiple entires under a particular author are listed chronologically. Prefaces to the various series supply historical and technical information. There is an incomplete *Subject Index* to the *Catalogue* (Cambridge: Cambridge University Press, 1908–1914. 4 vols.), the first volume of which covers "Pure Mathematics." See also item 20.

2281. Wolffing, Ernst. *Mathematischer Bücherschatz*. I. Teil: *Reine Mathematik. Abhandlungen zur Geschichte der mathematischen Wissenschaften mit Einschluss ihrer Anwendunge*, no. 16. Edited by Moritz Cantor. Leipzig: B. G. Teubner, 1903. xxxvi + 416 pp.

Designed as a catalogue of the most important books on pure mathematics published during the 19th century. Entries are listed alphabetically under 313 headings, including history of mathematics and philosophy of mathematics. Although criticized as incomplete, this work is an excellent tool for exploration of the non-periodical literature of the 19th century, and as such nicely complements the Royal Society's *Catalogue of Scientific Papers* (item 2280) which covers the periodical literature of the same period. A second part (on applied mathematics) was promised but never published.

Source Books and Surveys

2282. Birkhoff, Garrett, ed., with the assistance of Uta Merzbach. *A Source Book in Classical Analysis*. (Source Books in the History of the Sciences, edited by Edward H. Madden.) Cambridge, Mass.: Harvard University Press, 1973.

"A panoramic view" of the 19th-century development of systematic general theories of functions of real and complex variables. English translations of major papers on classical analysis, with general introductory remarks. Includes hitherto-untranslated material, and regularly preserves important original terms and words alongside translations. Also offers informative footnotes, and a short, partially annotated bibliography. Second half explores interactions between analysis and mathematical physics. See also item 101.

2283. *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*. Leipzig: B. G. Teubner, 1898–1935. 6 vols. in 23 parts.

A major survey of turn-of-the-century mathematics and its applications, featuring review articles written by eminent (predominantly German) mathematicians, including Hilbert, Hölder, Pringsheim, and Study. The articles are divided into six major categories: 1. arithmetic and algebra, 2. analysis, 3. geometry, 4. mechanics, 5. physics, and 6. geodesy, geophysics, and astronomy; they are rich in footnotes and most contain bibliographies. The volumes on mechanics were edited by Klein and C. H. Müller. French mathematicians planned a revised (more historical) version of this encyclopedia, the *Encyclopédie des sciences mathématiques pures et appliquées*, edited by Jules Molk, only 32 installments of which appeared between 1904 and 1916. See also items 5, 2896.

2284. Smith, David Eugene, ed. *A Source Book in Mathematics*. (Source Books in the History of the Sciences, edited by Gregory D. Walcott.) New York: McGraw-Hill, 1929. Reprinted New York: Dover Publications, 1959.

Selections from major mathematical publications from roughly 1450 through 1900. Divided into five sections: Number; Algebra; Geometry; Probability; and Calculus, Functions, and Quaternions. Each selection appears in English and is preceded by brief remarks introducing it and its author. Rich in 19th-century materials, the collection includes excerpts from works by Abel, Bolyai, Chebyshev, Galois, H. Grassmann, Kummer, Riemann, and Wessel. At its publication this book was somewhat of a landmark since it featured many original English translations of important parts of mathematical classics done by distinguished historians of mathematics. It is still useful to beginning English-reading students of the history of mathematics as a handy introduction to the mathematical classics and to the flavor of mathematics through 1900. See also items 105, 3493.

Journals

2285. *Acta Mathematica*.

Multilingual journal originally edited by Mittag-Leffler. Appearing in 1882, volume 1 carried articles by such eminent mathematicians as L. Fuchs, Goursat, Hermite, Picard, and Poincaré. Subsequent 19th-century contributors included: Beltrami, G. Cantor, Darboux, Hill, S. Kowalevski, Minkowski, M. Noether, Stieltjes, Chebyshev, and Weierstrass. Volume 10 contains a comprehensive name index. There is also an index to volumes 1 through 35, *Acta Mathematica, 1882–1912: Table générale des tomes 1–35*, edited by Marcel Riesz (Uppsala: Almqvist & Wiksells boktr., 1913). This journal is still published.

2286. *Cambridge and Dublin Mathematical Journal*.

Successor to the *Cambridge Mathematical Journal*. Appeared in nine volumes between 1846 and 1854, under the editorship of W. Thomson, Lord Kelvin. Carried articles by such major British mathematicians as De Morgan and W. R. Hamilton. Was replaced in 1857 by the *Quarterly Journal of Pure and Applied Mathematics*.

2287. *Cambridge Mathematical Journal*.

First major British journal devoted exclusively to mathematics. Founded in 1837 by D. F. Gregory and R. Ellis. Four volumes appeared between 1839 and 1845, carrying articles by G. Boole, De Morgan, and others. This journal is one of two major sources on Gregory, most of whose articles and whose main obituary notice were published in it. The journal continued from 1846 through 1854 as the *Cambridge and Dublin Mathematical Journal*, which was followed in 1857 by the *Quarterly*

Journal of Pure and Applied Mathematics. Volume 1 of the *CDMJ* contained an index to the *CMJ*.

2288. *The Gentleman's Magazine*.

English monthly periodical circulated between 1731 and 1907. Title varied. Originated the term "magazine" in publishing. Carried articles on wide-ranging topics, poetry, drawings, and numerous other features. Most items appeared anonymously. Of use for occasional reviews of mathematical books and obituary notices of leading 19th-century British mathematicians.

2289. *Jahrbuch über die Fortschritte der Mathematik*.

Critical year-by-year review of major mathematical books, pamphlets, and articles. Appeared in 68 volumes from 1871 through 1944, covering non-German as well as German publications from 1868 through 1942. (Volume 2 [1872] reviewed the literature from 1869 and 1870.) Entries are drawn from pure and applied mathematics and from the history and philosophy of mathematics, and are arranged topically. A name index appears at the end of each volume. Although criticized for uneven quality, this periodical remains a handy guide to mathematical publications through the early 1940s and to contemporary opinions thereof. The full text of the *Jahrbuch* is being converted into electronic database form by the Electronic Research Archive for Mathematics. The project is sponsored by the Deutsche Forschungsgemeinschaft and supervised by Elmar Mittler and Bernd Wegner. The editors of the database are Dennis, Keith and Bernd Wegner. See the web site Jahrbuch-Project (`http://www.emis.de/projects/JFM/`) and also item 33.

2290. *Journal de mathématiques pures et appliquées*.

One of the leading mathematical journals of the 19th century. Also known as the *Journal de Liouville* after Joseph Liouville, its founder and editor from 1836 through 1874. Authors of articles appearing in this journal during the 19th century included: Cauchy, Cayley, Duhem, Eisenstein, Hermite, C. G. Jacobi, C. Jordan, Painlevé, Plücker, Sturm, and Chebyshev. In 1846 (volume 11) the *Journal* carried posthumously Galois's major work, carefully edited by Liouville. This journal is still published today. Earlier volumes have been reprinted (Nendeln/Liechtenstein: Kraus, 1976).

2291. *Journal für die reine und angewandte Mathematik*.

A major mathematical journal of the 19th century. Also known as *Crelle's Journal* after August Leopold Crelle who founded it in 1826 and edited volumes 1–52 (1826–1856). Carried articles by Abel, Cayley, Dirichlet, Eisenstein, C. G. Jacobi, Kronecker, Kummer, Möbius, Plücker, J. Steiner, and Weierstrass. Still published today.

2292. *Mathematische Annalen.*

Multilingual journal founded in 1868 by Clebsch and Neumann. Nineteenth-century issues carried articles by such mathematicians as Beltrami, Bessel, Cayley, Hankel, C. Jordan, Klein, Lie, and M. Noether. An index appeared at the end of the century: A. Sommerfeld, *Genealregister zu den Bänden 1–50* (Leipzig: B. G. Teubner, 1898). This journal is still published.

2293. *Monthly Notices of the Royal Astronomical Society.*

A major publication of the Royal Astronomical Society. Volume 1 appeared in 1827. Contains fairly detailed summaries of papers read before the Society and noteworthy obituary notices of 19th-century British mathematicians. Since in its early decades the RAS included eminent mathematicians and mathematical practitioners, this is an important source for 19th-century British mathematics. Still published.

2294. *Quarterly Journal of Pure and Applied Mathematics.*

Journal which appeared in 1857 as replacement for the defunct *Cambridge and Dublin Mathematical Journal.* Nineteenth-century editors and assistants included: Sylvester, Stokes, Cayley, and Hermite. Articles by editors, Clifford, Cockle, De Morgan, Salmon, Spottiswoode, Tait, and W. Thomson (Lord Kelvin). Volume 15 contained an index to volumes 1–15; volume 30, an index to volumes 16–30. The last volume (33) was published in 1927. Reprinted Amsterdam: Swets & Zeitlinger, 1966.

2295. *Transactions of the Cambridge Philosophical Society.*

An essential source for British mathematics. Sponsored by the Cambridge Philosophical Society, which was founded in 1819 at the University of Cambridge for "the advancement of Natural Philosophy." Twenty-three volumes were published at irregular intervals from 1822 through 1928. Contributors included: Babbage, Cayley, G. Green, J. F. W. Herschel, Maxwell, Stokes, and Todhunter. Some British mathematicians, such as De Morgan, published substantial portions of their original research in this journal.

2296. *Transactions of the Royal Irish Academy.*

Major journal of the early Royal Irish Academy, first published in 1787 and then irregularly through 1907. Important source of articles by 19th-century Irish mathematicians and scientists, including W. R. Hamilton, Lardner, and Lloyd.

General Histories

2297. Ball, Walter W. Rouse. *A History of the Study of Mathematics at Cambridge*. Cambridge: Cambridge University Press, 1889, xvii + 264 pp.

A useful guide to mathematicians and mathematical trends associated with the University from the Middle Ages through the mid-third of the 19th century. Also provides an introduction to the evolution of mathematical education at Cambridge, including a chapter on the mathematical tripos. Valuable footnote references to primary sources. See also item 3887.

2298. Bourbaki, Nicolas. *Eléments d'histoire des mathématiques.* Paris: Hermann, 1960; revised 2nd ed., 1969 ; new ed., rev. and augmented, 1974; nouv. tirage.Paris: Masson, 1984, 376 pp. Translated as †Elements of the History of Mathematics† by John Meldrum, Berlin; New York: Springer-Verlag, 1994, viii + 301 pp.

The view from Nancago. It mostly describes the history of those branches of mathematics which the author has discussed elsewhere in his *Éléments*, so it is one of the few accounts of nineteenth- and twentieth-century topics. Dieudonné's *Abrégé d'Histoire* is, not surprisingly, somewhat similar. See also items 886, 2337.

2299. Klein, F. *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert.* Berlin: Springer Verlag, 1926–1927. Reprinted in 1 vol. New York: Chelsea, 1967. Also in English, translated by M. Ackerman, *Development of Mathematics in the 19th Century.* Brookline, Mass.: Math Sci. Press, 1979.

An unsurpassed account, by one of the century's leading figures, enlivened by personal comments, and always lucid in its account of the mathematics. It considers Gauss's work in pure and applied mathematics, the French school around the École Polytechnique, Crelle's *Journal* and German mathematics, algebraic geometry, the British school of mathematical physics, the function theory of Riemann and Weierstrass, algebraic curves, group theory and function theory (particularly Poincaré's automorphic functions) and, in an incomplete second part, linear invariant theory, special relativity, and Riemannian manifolds. The English translation contains as an appendix "Kleinian Mathematics from an Advanced Standpoint" by R. Hermann, pp. 363–630. See also items 2719 and 3047.

2300. Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972. New York: Oxford University Press, 1990.

Most comprehensive English-language history of mathematics and its applications. More than half deals with post-1800 mathematics, with the bulk devoted to the 19th century. This highly recommended book stresses concepts rather than biography, applied rather than pure mathematics.

Mathematical explanations often accompany the history, permitting the author to describe the work as an "historical introduction to mathematics." In addition, there are useful bibliographies at the ends of chapters and some footnotes. Reviewers have lavishly praised this standard history, one singling out its treatment of 19th-century analysis as exemplary of the author's historical and expository talents. See also items 902, 2225, 2345, 2720, 3029, 3812.

2301. Merz, John Theodore. *A History of European Scientific Thought in the Nineteenth Century*. Edinburgh and London: William Blackwood & Sons, 1904–1912. Reprinted Gloucester, Mass.: Peter Smith, 1976. 4 vols.

Written as a contribution to the "unification of thought." Explores some of the interrelations among the mathematics, science, and philosophy of the 19th century. Volumes 1 and 2 focus on science; volumes 3 and 4 (entitled *A History of European Thought in the Nineteenth Century*), on philosophy. Mathematical developments are treated in Volume 2, Chapter 12: "On the Statistical View of Nature" and Chapter 13: "On the Development of Mathematical Thought during the Nineteenth Century." This work is recommended primarily as a "treasure-trove of bibliographical information." Abundant discursive footnotes cite valuable primary and secondary materials.

2302. Prasad, Ganesh. *Some Great Mathematicians of the Nineteenth Century: Their Lives and Their Works in Three Volumes*. Benares, India: Benares Mathematical Society, 1933–1934. 2 vols.

Includes biographies, partial bibliographies, and generous selections from major works. More descriptive than interpretative; some brief analysis in the form of quotations from other secondary sources. Volume 1 covers Gauss, Cauchy, Abel, C. G. Jacobi, Weierstrass, and Riemann; Volume 2 covers Cayley, Hermite, Brioschi, Kronecker, Cremona, Darboux, Cantor, Mittag-Leffler, Klein, and Poincaré. Volume 3 was never published. No index.

2303. Taylor, Eva G. R. *The Mathematical Practitioners of Hanoverian England, 1714–1840*. Cambridge: Cambridge University Press, 1966, 503 pp.

A sequel to the author's *Mathematical Practitioners of Tudor and Stuart England* (items 1959, 2107), this book is a pioneer reference work treating 2,282 great and not-so-great mostly British artisans, navigators, surveyors, mechanics, instructors in the mathematical arts, instrument makers, and the like. It is divided into two parts, the first of which presents a chronological overview of mathematical practice through 1840. By the latter date, the author implies, the professionalization of science and its division into pure and applied destroyed the common link among mathematical practitioners. Of major interest is part 2, which contains bibliographies of the practitioners, arranged alphabetically in successive decades. The work includes a brief statement on sources consulted and two indexes, but has been criticized as difficult to use since some bibliographies are not indexed and the biographies are usually undocumented. See also item 3349.

Biographical Studies

This section of the bibliography is highly selective; a thorough compilation of biographical literature on 19th-century mathematicians would be prohibitively long. Readers are again reminded to use standard guides like Gillispie's *Dictionary of Scientific Biography*, item 8, and Poggendorff, items 16 and 17, as preliminary introductions to specific figures.

Collections

2304. Arago, Dominique François. *Oeuvres complètes.* Vols. 1–3. Paris: Gide et J. Baudry, 1854–1855.

Principally collections of biographical notices written by the author as Secrétaire perpétuel de l'Académie des Sciences. Covers Ampère, Carnot, Fourier, Fresnel, Monge, Poisson, and other European mathematicians and scientists. English translations of ten of these biographies, accompanied by new notes, appear in *Biographies of Distinguished Scientific Men*, translated by W. H. Smyth, Baden-Powell, and Robert Grant (London: Longmans, Brown, Green, 1857).

2305. Macfarlane, Alexander. *Lectures on Ten British Mathematicians of the Nineteenth Century.* (Mathematical Monographs, edited by Mansfield Merriman and Robert S. Woodward, no. 17.) New York: John Wiley & Sons, 1916.

Introductions to some of the leading British mathematicians of the 19th century: G. Boole, Cayley, Clifford, De Morgan, W. R. Hamilton, Kirkman, Peacock, Smith, Sylvester, and Todhunter. While criticized as unfocused, Macfarlane's biographical sketches (originally delivered as lectures) contain some insightful comments on the personalities and major contributions of these mathematicians. Occasional juicy quotations, but no bibliography or footnotes.

2306. Macfarlane, Alexander. *Lectures on Ten British Physicists of the Nineteenth Century.* (Mathematical Monographs, edited by Mansfield Merriman and Robert S. Woodward, no. 20.) New York: John Wiley & Sons, 1919.

A supplement to the author's *Lectures on Ten British Mathematicians of the Nineteenth Century*, item 2305, and characterized by the same strengths and weaknesses. Covers "mathematicians whose main work was in physics, astronomy, and engineering": Adams, Airy, Babbage, Herschel, Maxwell, Rankine, Stokes, Tait, W. Thomson (Lord Kelvin), and Whewell.

2307. Marie, Maximilien. *Histoire des sciences mathématiques et physiques.* Paris: Gauthier-Villars, 1883–1888. 12 vols.

Offers brief biographies with bibliographical notices of major and lesser mathematicians from ancient times through the 19th century. Volumes 8 through 12 cover the latter century. There is an index at the end of each volume and a general index of names at the back of the last volume. Especially useful for references to minor French mathematicians; weak on British mathematics.

Abel, Niels Henrik (1802–1829)

2308. Ore, Øystein. *Niels Henrik Abel.* Minneapolis: University of Minnesota Press, 1957, 277 pp. Reprinted New York: Chelsea Pub. Co., 1974.

An extremely valuable biography, but thin on the mathematics.

Babbage, Charles (1792–1871)

2309. Dubbey, John M. *The Mathematical Work of Charles Babbage.* Cambridge: Cambridge University Press, 1978, 235 pp.

Pioneer study describing Babbage's work on the calculus of functions, symbolical algebra, mathematical notation, and computers, and, to a lesser extent, analysis, probability, and geometry. Offers an interesting perspective on the early 19th-century Cambridge mathematical community (including Peacock and J. F. W. Herschel) which spawned the Analytical Society. Shows, for example, that in 1821 Babbage produced a manuscript which contained the seeds of symbolical algebra later developed by Peacock. Also argues that Babbage formulated "the major ideas upon which all modern computers are constructed." Because of the rich original source material which Dubbey has discovered and described, this book is a prerequisite to research on British mathematics of Babbage's period. A reviewer has criticized its failure to retain all of Babbage's original notation. See also item 2486.

Cayley, Arthur (1821–1895)

2310. Cayley, Arthur. *The Collected Mathematical Papers of Arthur Cayley.* Edited by Arthur Cayley and A. R. Forsyth. Cambridge: Cambridge University Press, 1889–1897. 13 vols. and a supplementary vol.

Cayley's published papers, listed chronologically and numbered consecutively throughout the 13 volumes (from 1 through 967). As editor of the early volumes, Cayley listed but did not reprint papers which were "controversial" (contained serious errors) or were merely translations of ones already included in the collection. Cayley also added "Notes and References" to the papers in volumes 1 through 8. Volume 8 begins with a biographical notice of Cayley and a list of courses he taught. The collection contains an occasional hitherto-unpublished paper. The supplementary volume provides a list of all the papers in the collection, arranged according to their assigned numbers, and an index of subjects and names. This work has been reprinted (New York: Johnson Reprint, 1963).

De Morgan, Augustus (1806–1871)

2311. De Morgan, Sophia Elizabeth. *Memoir of Augustus De Morgan, with Selections from His Letters*. London: Longmans, Green, 1882.

Best available biography of De Morgan. Written by his wife. Not a scientific biography; but offers valuable information on De Morgan's personal life and professional career. Also includes substantial selections from his correspondence. Very useful bibliography.

Fourier, Joseph (1768,1830)

2312. Grattan-Guinness, Ivor, in collaboration with J. R. Ravetz. *Joseph Fourier, 1768–1830*. Cambridge, Mass.: MIT Press, 1972, xii + 516 pp.

A thorough discussion, complete with biography and bibliography, centered on Fourier's hitherto unpublished monograph of 1807 on heat diffusion. See also item 3286.

Galois, Évariste (1811–1832)

2313. Rigatelli, Laura Toti. *Évariste Galois, 1811–1832*. Basel: Birkhäuser, 1996.

2314. Taton, René. "Évariste Galois et ses biographes: de l'histoire aux légendes. Un parcours en histoire des mathématiques: travaux et recherches", *Sci. Tech. Perspect.* (Univ. Nantes, Nantes) 26 (1993), 155–172.

A critical history of the biographical efforts directed at Évariste Galois.

Gauss, Carl Friedrich (1777–1855)

2315. Biermann, Kurt-R. ed. *Carl Friedrich Gauss. Der "Fürst der Mathematiker" in Briefen und Gesprächen*. Leipzig: Urania-Verlag, 1990.

Carl Friedrich Gauss. The "Prince of mathematicians" in letters and discourse. A life of Gauss followed by 160 letters and quotations in chronological order. There is also a carefully prepared index of sources and secondary literature.

2316. Brendel, M., F. Klein, and L. Schlesinger. "Materialen für eine wissenschaftliche Biographie von Gauss". In Gauss's *Werke* X (2) (1922–1923).

Particularly valuable essays on Gauss's work in number theory, analysis, and astronomy, written by expert authors with an intimate knowledge of Gauss's *Nachlass*, which they edited.

2317. Coxeter, H. S. M. "Gauss as a Geometer". *Historia Mathematica* 4 (1977), 379–396.

2318. Dieudonné, Jean. *L'oeuvre mathématique de C. F. Gauss*. Paris: Palais de la Découverte, 1962.

Stresses Gauss's abstract, unifying approach to mathematics. Re-worked in the author's "Carl Friedrich Gauss: A Bi-Centenary", *Bulletin Mathématique* 2 (1978), 61–70.

2319. Dunnington, G. W. *Carl Friedrich Gauss, Titan of Science*. New York: Exposition Press, 1955.

Useful on his career if somewhat superficial on his scientific achievements.

2320. Kaufmann-Bühler, Walter. *Gauss. A Biographical Study*. Berlin/New York: Springer-Verlag, 1981. Translated into German as *Gauss. Eine biographische Studie*. Berlin/New York: Springer-Verlag, 1987; and into Russian as *Gauss. Biograficheskoe issledovanie*. Moscow: "Nauka", 1989.

Well written, this account concentrates more on the mathematics than the historical issues of Gauss's life. See remarks by P. J. Wallis in **MR** 82j:01066.

2321. Merzbach, Uta C. compiler. *Carl Friedrich Gauss: A Bibliography*. Wilmington, Del.: Scholarly Resources Inc., 1984. xxv + 551 pp.

The definitive guide to primary resources on Gauss. (1) "Primary Work" provides a checklist of all publications by Gauss (including those posthumously published) and collections of his writings, along with translations and reissues. (2) A listing of letters includes all published letters and the letters in the Gauss Archives in the Göttingen University library; not, however, the Gauss related material in the University Archives which is, presumably, of an administrative nature and of less scientific interest. (The appendixes cite over 40 libraries in Europe and the United States as archival sources.) The arrangement is chronological and provides for each letter the correspondent's name and its place of publication, if any. (3) "Secondary Work" lists selected works dealing with Gauss, his family or his work in a specific way. (4) Appendices: list of letters by location (excluding those in Göttingen); index to names of authors, editors, and translators; and a list of publications by language. (5) A 200-page name index includes all names of individuals who corresponded with Gauss, had works reviewed by him, or are mentioned in publications or letters of his. There is also a 15-page topical index including such headings as: astronomy, chess, instruments (subdivided into 138 instruments), logarithms, and philately. Also included is a chronology of publications, letters and secondary literature.

2322. Reichardt, H. *Gauss und die nicht-euklidische Geometrie*. Leipzig: Teubner, 1976.

2323. Wussing, H. *C. F. Gauss*. Leipzig: Teubner, 1974.

Hamilton, William Rowan (1805–1865)

2324. Graves, Robert Perceval. *Life of Sir William Rowan Hamilton*. Dublin: Hodges, Figgis, 1882–1889. New York: Arno Press, 1975. 3 vols.

Massive Victorian "life and letters," written by a friend. Offers a wealth of biographical detail, supplemented by selections from Hamilton's poems, correspondence, and assorted manuscripts. The author's sense of propriety, however, led him to restrict coverage of very personal details and remarks on persons still living; his mathematical limitations precluded any substantial analysis of Hamilton's major work. Volume 3 features a complete bibliography of Hamilton's publications, as well as extensive extracts from the Hamilton-De Morgan correspondence. Each volume includes an index.

2325. Hankins, Thomas. *Sir William Rowan Hamilton*. Baltimore, London: Johns Hopkins University Press, 1980.

A comprehensive biography of Hamilton and the best starting point for information on him and his work. See also item 2687.

2326. Mathews, Jerold. "William Rowan Hamilton's Paper of 1837 on the Arithmetization of Analysis". *Archive for History of Exact Sciences* 19 (1978), 177–200.

A discussion of the content and reception of the ideas on arithmetization of analysis contained in Hamilton's famous essay. Argues that the essay introduced concepts (including one related to the cut in the rationals) found in the later work of such mathematicians as Peano and Dedekind. Concludes, however, that Hamilton's essay exercised no direct influence on the arithmetization of analysis in the late 19th century. Attributes this lack of influence to the relative obscurity of the journal in which Hamilton published, his metaphysical style, and his mathematical isolation. Good bibliography. See also item 2747.

2327. O'Donnell, Seán. *William Rowan Hamilton. Portrait of a Prodigy.* With a foreword by A. J. McConnell. (Profiles of Genius Series, 1.) Dún Laoghaire: Boole Press, 1983.

"The present work has a different purpose" from the comprehensive study of Sir William Rowan Hamilton by T. L. Hankins (item 2325), explains the author. "It is an attempt to come to grips with Hamilton's formidable personality rather than his achievements".

Monge, Gaspard (1746,1818)

2328. Taton, René. *L'oeuvre scientifique de Monge.* Paris: Presses Universitaires de France, 1951, 441 pp.

Reviews Monge's life, including his important work in setting up the École Polytechnique, and then his work in descriptive, analytic, and infinitesimal geometry and other subjects, including partial differential equations. See also items 2277, 3066.

Peirce, Benjamin (1809–1880)

2329. Archibald, Raymond Clare, ed. *Benjamin Peirce, 1809–1880.* Oberlin, Ohio: Mathematical Association of America, 1925.

Thirty-page collection of valuable biographical and bibliographical material on Peirce. Includes reminiscences by his former Harvard students: C. W. Eliot, A. L. Lowell, W. E. Byerly, and A. B. Chace; a biographical sketch by the editor; a list of surviving portraits of Peirce; and a partially annotated bibliography. Recommended for the bibliography, anecdotes, and glimpses of Peirce as mathematics professor. No index. Also published in *American Mathematical Monthly* 32 (1925), 1–30.

Peirce, Charles S. (1839–1914)

2330. Brent, Joseph. *Charles Sanders Peirce: A Life.* Bloomington, Indiana: Indiana University Press, 1993.

This, the first book-length biography of the United States's greatest philosopher, concentrates on his fascinating life rather than his philosophical, logical, or mathematical work.

2331. Eisele, Carolyn. *Studies in the Scientific and Mathematical Philosophy of Charles S. Peirce: Essays by Carolyn Eisele.* Edited by R. M. Martin. (Studies in Philosophy, no. 29.) The Hague and Paris: Mouton, 1979.

Collection of 30 published and unpublished essays written from 1951 through 1976. Covers Peirce's mathematics, science, logic, philosophy, history of science, and mathematics textbook writing. Provides a good introduction to his varied mathematical interests which included non-Euclidean geometry, linear algebra, the four-color problem, the infinite, n-valued logic, and infinitesimals. Based on a careful analysis of primary sources, the collection argues that Peirce was "primarily a *mathematician*, logician, and philosopher" and that his mathematics influenced his philosophy. Scattered throughout the essays is some useful information on the American mathematical community of the late 19th and early 20th centuries. See also item 2332.

2332. Peirce, Charles S. *The New Elements of Mathematics by Charles S. Peirce.* Edited by Carolyn Eisele. The Hague and Paris:

Mouton; Atlantic Highlands, New Jersey: Humanities Press, 1976. 4 vols. in 5 books.

Well-organized, well-indexed collection of Peirce's mathematical writings, most of which were hitherto unpublished. Each volume bears a separate title, descriptive of its contents. Thus, Volume 1: *Arithmetic* contains material for an unpublished arithmetic textbook. Volume 2: *Algebra and Geometry* reproduces "Elements of Mathematics," another textbook manuscript, and Peirce's notes towards an updated version of an elementary geometry textbook originally published by his father, Benjamin. Described by one reviewer as "of greatest mathematical interest." Volume 3: *Mathematical Miscellanea* appears in two books, with Book 1 offering assorted manuscripts and Book 2 featuring Peirce's mathematical correspondence and items from *The Nation*. Displaying Peirce's mathematical breadth, this volume deals with trigonometry, probability, finite differences, Boolean algebra, the four-color problem, map projections, linear algebra, matrices, non-Euclidean geometry, n-valued logic, the mathematical infinite, and additional topics. Volume 4: *Mathematical Philosophy* emphasizes logic and the philosophy of science and mathematics. All volumes open with useful introductions by the editor and include indexes of names and subjects. See also item 2331.

MATHEMATICS IN THE 20th CENTURY

Since 1900, mathematics has exhibited both points of continuity and points of discontinuity with its past. It has continued to grow exponentially and to develop at ever higher levels of abstraction and generalization the areas explored in the previous century. On the other hand, many new fields have arisen which would be barely comprehensible to a nineteenth-century mathematician. Writing the history of twentieth-century mathematics is impeded by the highly technical nature of the material and by the difficulty of gaining an adequate perspective on recent developments. Nevertheless, such recent history is often intriguing, thanks to the abundance of source material and to the possibility of oral history.

As with the eighteenth and nineteenth centuries, this twentieth-century section is mainly confined to general and biographical works devoted to the period. Not included are works devoted to one of the modern mathematical topics represented by separate sections of the bibliography. Biographies of women mathematicians will also be found in the section devoted to that topic.

General Works

2333. Albers, Donald J., and G. L. Alexanderson, eds. *Mathematical People.* Boston: Birkhäuser, 1985. xvi + 372 pp.

This volume contains 24 interviews with contemporary mathematicians, and one article of reminiscences of Solomon Lefschetz by Albert Tucker of Princeton. It is purely biographical and contains no technical mathematics at all.

2334. Albers, Donald J., Gerald I. Alexanderson, and Reid, Constance, eds. *More Mathematical People.* Boston: Harcout Brace Jovanovich, 1990, xvii + 375 pp.

This book is a continuation of item 2333, and contains interviews with 18 more contemporary mathematicians, including several women. Like its predecessor, it is especially useful as motivation for high-school students.

2335. Birkhoff, Garrett, ed. "Proceedings of the American Academy Workshop on the Evolution of Modern Mathematics..." *Historia Mathematica* 2 (1975), 425–615.

The 21 articles in this symposium volume are divided into five parts: historiography, history of foundations, contemporary foundations of mathematics, algebra, and analysis. The section on historiography includes papers by J. V. Grabiner (the historian vs. the mathematician), K. O. May (the nature of good history), E. Koppelman (progress in mathematics), H. Tropp (oral history), and M. J. Crowe (laws of history). The second section consists of two papers by I. Grattan-Guinness (the Axiom of Choice; Russell) and one by H. Freudenthal (Brouwer's topology). Contemporary foundations include papers by E. Bishop (constructivism), G. Sacks (against foundations), and H. Putnam (mathematical truth). The section on algebra consists of lectures by J. Dieudonné (fusion), A. Baker (Catalan's conjecture), G. Mackey (harmonic analysis), T. Hawkins (progress without fusion), and S. Abhyankar (algebraic geometry). Finally, the essays on analysis are by F. E. Browder (functional analysis), A. Zygmund (Fourier series), J. P. Kahane (Brownian motion), and J. B. Diaz (progress).

2336. Bottazzini, Umberto. *Il Flauto di Hilbert: Storia della Matematica Moderna e Contemporanea.* Torino: UTET, 1990, vii + 455.

2337. Bourbaki, Nicolas. *Eléments d'histoire des mathématiques.* 2nd ed. Paris: Hermann, 1969. tp[]

Written to illuminate the predecessors of the polycephalic Bourbaki, this volume includes material on the twentieth century in almost every one of its 23 sections. However, the sections in which this century predominates are those on noncommutat ive algebra, topological spaces, uniform spaces, metric spaces, function spaces, topological vector spaces, integration, and Haar measure. See also items 886, 2298.

2338. Browder, Felix E., ed. *Mathematical Developments Arising from Hilbert Problems.* (Proceedings of Symposia in Pure Mathematics, Vol. 28.) Providence: American Mathematical Society, 1976. xii + 628 pp.

Includes a translation of Hilbert's original lecture on mathematical problems, delivered in Paris in 1900. There follows a short essay, with 27 subsections, on important current problems in mathematics—from foundations to mathematical physics. The bulk of the volume is devoted to 23 essays on mathematical research and problems, especially recent ones, arising from those originally posed by Hilbert.

2339. Casacuberta, C., and M. Castellet. *Mathematical Research Today and Tomorrow: Viewpoints of Seven Fields Medalists.* (Lecture Notes in Mathematics, No. 1525.) Berlin: Springer-Verlag, 1992. vii + 112 pp.

This volume presents the illuminating and varied thoughts of Fields medalists René Thom, S. P. Novikov, Shing-Tung Yau, Vaughan F. R. Jones, Stephen Smale, Gerd Faltings, and Alain Connes on what mathematics is and what it should be.

2340. Dang, Ya Ru. "The Development of Mathematics in the Light of the Mathematical Subject Classification". (In Chinese). *Journal Xinjiang University, Natural Sciences* 12 (2) (1995), 48–55.

An attempt to interpret the development of mathematics by having recourse to review journals.

2341. Dieudonné, Jean. "General Orientation of Pure Mathematics in 1973". (In Spanish). *Boletín de Matemáticas* 12 (1–6) (1978), 214–222.

The author, one of the century's outstanding algebraic analysts, gives his view of the "nobles" and "servants" among twentieth-century mathematical results.

2342. Dieudonné, Jean. "Present Trends in Pure Mathematics". *Advances in Mathematics* 27 (1978), 235–255.

An attempt to discern some patterns in contemporary trends in mathematics, such as the use of structures, category theory, and sheaves. The particular subdisciplines treated (briefly and densely) are foundations, algebraic topology, differential geometry, differential equations, Banach spaces, harmonic analysis, Lie groups, algebraic geometry, and number theory. See also Dieudonné's *Panorama des mathématiques pures: Le choix bourbachique*,(Paris: Gauthier-Villars, 1977).

2343. Halmos, Paul R. *I Have a Photographic Memory.* Providence: American Mathematical Society, 1987, vii + 613 pp.

A collection of photographs of prominent mathematicians taken by the author, himself a prominent mathematician.

2344. Jacobs, Konrad. "Entwicklungslinien in der Mathematik im 20. Jahrhundert". *Mathematische Semesterberichte* 33 (1) (1986), 26–54.

This article focuses mostly on the sociological aspects of mathematics as a profession, but also gives a survey of some important problems being attacked by mathematicians.

2345. Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972. xvii + 1238 pp.

Chapters 43–51 primarily treat the twentieth century. These concern mathematics circa 1900 (the study of arbitrary structures), the theory of functions of real variables (measure and integration), integral equations (Hilbert's contribution), functional analysis (Volterra, Fréchet, and von Neumann), divergent series (summability), differential geometry (tensors), abstract algebra (groups, rings, fields), topology (point-set and combinatorial), and the foundations of mathematics (set theory, mathematical logic, philosophy of mathematics). See also items 902, 2225, 2300, 2720, 3029, 3812.

2346. May, Kenneth O. "Growth and Quality of the Mathematical Literature". *Isis* 59 (1968), 363–371.

Analyzes the exponential growth of the mathematical literature from 1800 to 1950. Studies one subfield, the history of determinants, in more depth. His results suggest the relative proportion of six categories: new ideas (theorems, proofs, methods), applications, systematization, textbooks, duplications, and trivia. See also May's "Quantitative Growth of the Mathematical Literature", *Science* 154 (1966), 1672–1673.

2347. May, Kenneth O. *Index of the American Mathematical Monthly.* Washington, D.C.: Mathematical Association of America, 1977, vi + 269 pp.

Includes annual, author, and subject indexes for the first 80 volumes (1894–1973) of the leading expository journal in American mathematics. Many historical and quasi-historical articles are indexed. An expository preface (i–vi) explains the indexes, how to use them, plus two very informative sections, "How it was done," and "How it should have been done."

2348. Monastyrsky, Michael. *Modern Mathematics in the Light of the Fields Medal.* Wellesley, MA: AKPeters Ltd., 1997.

The author uses the Fields Medals as a guide to the development of modern mathematics, giving a complete and detailed history of this prize through the year 1994.

2349. Novikov, S. P. "My Generation in Mathematics". In Russian. *Uspekhi Matematicheskikh Nauk* 49, No. 6(300) (1994), 3–6.

Some thoughts on the recent development of mathematics by the distinguished Fields medalist. English translation in *Russian Mathematical Surveys* 49, no. 6 (1994), 1–4.

2350. Piers, Jean-Paul, ed. *The Development of Mathematics, 1900–1950.* Basel: Birkhäuser, 1994, xvii + 729 pp.

This book offers a chronological list of important mathematical papers from the first half of the twentieth century and a series of essays by experts on the development of various parts of the subject during that time.

2351. Rham, Georges de. "Quelques Souvenirs des Anées 1925–1950". *Cahiers du Séminaire d'Histoire des Mathématiques* 1 (1980), 19–36.

2352. Tropp, Henry S. "The Origins and History of the Fields Medals". *Historia Mathematica* 3 (2) (1976), 167–181.

The author traces the early history of the "Nobel Prize" of mathematics and its Canadian founder.

Studies of Individual Mathematicians

2353. Adem, José. "A Sketch of Solomon Lefschetz's Life in Mexico". In *Differential Equations (Third Mexico–U.S. Symposium, Mexico City, 1975).* (Mathematical Notes and Symposia, No. 2.) In Spanish. Mexico City: Fondo de Cultura Economica, 1976. 1–7.

A sketch of Lefschetz's life in Mexico, after his retirement from Princeton University.

2354. Alexanderson, G. L., ed. *The Pólya Picture Album: Encounters of a Mathematician*. Boston: Birkhäuser, 1987, 160 pp.

2355. Andler, Martin. "Entretien avec Trois Membres de Nicolas Bourbaki". *Gazette des Mathématiques*. 35 (1988), 48–49.

A discussion by three of the Bourbaki authors on the methods and achievements of the group.

2356. Beaulieu, Liliane. "A Parisian Café and Ten Proto-Bourbaki Meetings (1934–1935)." *The Mathematical Intelligencer* 15 (1) (1991), 27–35.

2357. Berndt, Bruce C. "Srinivasa Ramanujan". *American Scholar* 58 (1989), 234–244.

2358. Boas, R. P. "George Pólya, December 13, 1887–September 7, 1985." *Biographical Memoirs of the National Academy of Sciences* 59 (1990), 339–355.

2359. Borel, Armand. "Some Recollections of Harish-Chandra". *Current Science* 65 (1993), 919–921.

Personal recollections of the great twentieth-century analyst, listing his greatest achievements and telling something of the spiritual motivation of his work.

2360. Borgato, Maria Teresa, and Arturo Vaz Ferreira. "Giuseppe Vitali: Mathematical Research and Academic Activity after 1918". In *Italian Mathematics between the Two World Wars*. In Italian. Milan: Gargnano, 1987.

This article contains a study of Vitali's mathematical research (in considerable depth) and his administrative and teaching activity.

2361. Chandrasekharan, K. *Hermann Weyl. 1885–1985*. New York: Springer-Verlag, 1986, xi + 109 pp.

A report of the centenary of Weyl's birth, celebrated in Zürich at the Eidgenössische Technische Hochschule. The papers summarized here place Weyl's work in the perspective of twentieth-century mathematics and physics.

2362. Choquet, Gustave. "Notice sur les travaux scientifiques". *Historia Mathematica* 2 (1975), 153–160.

A summary of the influences on his research and of the research itself—on topology, measure theory, potential theory, and functional analysis. (Such a "Notice" exists for many French mathematicians and can often be found in their collected works.)

2363. Cooper, Necia Grant. *From Cardinals to Chaos: Reflections on the Life and Legacy of Stanislaw Ulam.* Cambridge, New York: Cambridge University Press, 1987, 320 pp.

This volume is a reprint of *Los Alamos Science*, No. 15 (1987). It contains three original articles by Ulam and a number of biographical articles about him.

2364. Dieudonné, J. "Regards sur Bourbaki". *Analele Universităţii Bucureşti, Matematică-Mecanică.* 18 (2) (1969), 13–25.

2365. Dubreil, Paul "Emmy Noether." *Cahiers du Séminaire d'Histoire des Mathématiques* 7 (1986), 15–27.

2366. Dugac, Pierre. "Notes et documents sur la vie et l'oeuvre de René Baire". *Archive for History of Exact Sciences* 15 (1976), 297–383.

A biography of Baire, together with many previously unpublished documents on his life and work. Especially important is his correspondence with V. Volterra.

2367. Grattan-Guinness Ivor. "Russell and G. H. Hardy: A Study of their Relationship". *Russell* 11 (1992), 165–179.

2368. Griffiths, Phillip, Spencer, Donald, and Whitehead, George "Solomon Lefschetz, September 3, 1884–October 5, 1972". *Biographical Memoirs of the National Academy of Sciences* 61 (1991–92), 271–313.

2369. Grunsky, H. "Ludwig Bieberbach zum Gedächtnis". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 88 (1986), 190–205

A biography of the mathematician who led German mathematics during the Nazi era.

2370. Guedj, Denis "Nicholas Bourbaki, Collective Mathematician: An Interview with Claude Chevalley". *Mathematical Intelligencer* 7 (2) (1985), 18–22.

2371. Halmos, Paul R. *I Want to be a Mathematician: An Automathography.* New York: Springer-Verlag, 1985, xvi + 421 pp.

2372. Hardy, G. H. *A Mathematician's Apology.* Cambridge: Cambridge University Press, 1967.

This *apologia pro vita sua* contains a 50-page preface by C. P. Snow, in effect an affectionate reminiscence and biography. See also the biography by E. C. Titchmarsh in Hardy's *Collected Papers.*

2373. Hille, Einar. "In Retrospect". *The Mathematical Intelligencer* 3 (1) (1980–81), 3–13.

The memoirs of a distinguished twentieth-century mathematician, published in lieu of an obituary. It contains glimpses of a number of other famous mathematicians.

2374. Hirschfeld, J. W. P. and, Wall, G. E.. “Thomas Gerald Room, 10 November 1902–2 April 1986”. *Biographical Memoirs of Fellows of the Royal Society* 33 (1987), 575–601.

The subject of this article was one of the leading figures in combinatorial design.

2375. Kac, Mark. *Enigmas of Chance: An Autobiography.* New York: Harper and Row, 1985, xxvii + 163 pp.

2376. Kanigel, Robert. *The Man Who Knew Infinity: A Life of the Genius Ramanujan.* New York: Scribner’s; Toronto: Collier Macmillan, 1991, ix + 438 pp.

2377. Kennedy, Hubert C. *Peano: Life and Works of Giuseppe Peano.* Dordrecht: Reidel, 1980, xii + 230 pp.

Based on extensive use of published and unpublished materials, this book provides a detailed personal and intellectual biography of Peano, especially his research in mathematical logic and his efforts on behalf of an international language. Includes appendices on Peano’s professors, the mathematicians in his school of logic, the papers of others that he submitted to the Academy of Sciences at Turin, and a complete bibliography of his published writings. See also Kennedy’s *Selected Works of Giuseppe Peano* (London: Allen and Unwin, and Toronto: University of Toronto Press, 1973).

2378. Kendall, D. G. “Andrei Nikolaevich Kolmogorov, 25 April 1903–20 October 1987”. *Biographical Memoirs of Fellows of the Royal Society* 37 (1991), 301–319.

2379. Kleene, Stephen C. “Kurt Gödel, April 28, 1906–January 15, 1978”. *Biographical Memoirs of Members of the National Academy of Sciences* 56 (1987), 135–178.

2380. Kolata, G. B. “Hua Lo-Keng Shapes Chinese Math”. *Science* 210 (1980), 413–414.

A semi-popular biography of the most influential mathematician in contemporary China. See also the article by A. Feferman, “Professor Hua Lo-Keng on Tour”, *San Francisco Chronicle*, March 15, 1981, pp. 19–21.

2381. Kolata, G. B. “Gian-Carlo Rota and Combinatorial Math”. *Science* 204 (1979), 44–45.

A brief biography, based on an interview with Rota. Discusses the rise of combinatorics in recent years, as well as its relationship to linguistics and statistical mechanics.

2382. Langlands, R. P. “Harish-Chandra, 11 October 1923–16 October 1983”. *Biographical Memoirs of Fellows of the Royal Society* 31 (1985), 199–225.

2383. McKean, H. P. “Mark Kac, August 16,1914–October 25, 1984”. *Biographical Memoirs of the National Academy of Sciences.* 59 (1990), 215–235.

2384. Maz′ya, Vladimir, and Tatyana Shaposhnikova. *Jacques Hadamard, a Universal Mathematician.* Partially translated from Russian and French by Peter Basarab-Horwath. History of Mathematics, 14. Providence, R.I.: American Mathematical Society; London: London Mathematical Society, 1998. xxviii + 574 pp.

The book consists of 300 pages on the life of Hadamard, profusely illustrated with photographs and facsimiles of important documents, followed by 200 pages of detailed description of Hadamard's mathematics. See the detailed review by R. L. Cooke in **MR** 98m:01031.

2385. Morawetz, Cathleen S. “Giants”. *American Mathematical Monthly.* 99 (1992), 819–828.

The text of an invited address before the Mathematical Association of America in 1990, containing stories of applied mathematicians known personally to the author.

2386. Morawetz, Cathleen S. *The Last 75 Years: Giants of Applied Mathematics.* Washington, D.C.: Mathematical Association of America, 1991, 1 videocassette (NTSC; 1/2 inch; VHS) (45 min.).

The speaker was personally acquainted with the four giants (G. I. Taylor, T. von Karman, J. von Neumann, and N. Wiener), who were the pre-eminent applied mathematicians of their day, each of whom also made outstanding contributions to pure mathematics.

2387. Müller, Claus. “Erinnerungen an Hermann Weyl”. *Naturwissenschaftliche Rundschau* 38 (1985), 451–455.

2388. Parikh, Carol. *The Unreal Life of Oscar Zariski.* Boston: Academic Press, 1991, xxviii + 264 pp.

2389. Parshall, Karen Hunger. “New Light on the Life and Work of Joseph Henry Maclagan Wedderburn(1882–1948)”. In Sergei S. Demidov, ed. *Amphora: Festschrift für Hans Wussing.* Basel: Birkhäuser, 1992, 523–537.

2390. Purkert, Walter, and Hans-Joachim Ilgauds. *Georg Cantor 1845–1918.* Second edition. Vita Mathematica, 1. Basel/Boston, Mass.: Birkhäuser Verlag, 1987. 262 pp.

A useful source in German on Cantor, valuable to use in addition to the biography by Dauben (item 4070). Reviewed by Joseph W. Dauben in **MR** 88k:01043.

2391. Reid, Constance. *Hilbert.* New York: Springer, 1970. xi + 290 pp.

A detailed but anecdotal biography, based on extensive interviews with Hilbert's colleagues and students. Also includes a reprint of H. Weyl's lengthy article analyzing Hilbert's many contributions to mathematics.

2392. Reid, Constance. *Courant in Göttingen and New York: The Story of an Improbable Mathematician.* New York: Springer, 1976. ii + 314 pp.; 16 pls.

A very personal history, based on numerous interviews, of Courant and his institutional associations: the Mathematical Institute in Göttingen and the Courant Institute of Mathematical Sciences in New York City.

2393. Sánchez, Ron José Manuel. "Hermann Weyl, Científico-filósofo". *Theoria* 16–18 (1992), 703–713.

2394. Segal, Irving Ezra. "Norbert Wiener, November 26, 1894–March 18, 1964". *Biographical Memoirs of the National Academy of Sciences* 61 (1992), 389–436.

2395. Steinhaus, Hugo. "Stefan Banach, 1892–1945". *Scripta Mathematica* 26 (1961), 93–100.

Reminiscences together with a discussion of Banach's work in real and functional analysis.

2396. Traylor, D. R., et al. *Creative Teaching: Heritage of R. L. Moore.* Houston: University of Houston, 1972.

A study of Moore's life and work. Particular attention is paid to the innovative "Moore method" of teaching and to the controversy surrounding Moore's dismissal at the age of 87. Includes a lengthy list of Moore's academic descendants and their numerous publications.

2397. Troelstra, A. S. "The Scientific Work of A. Heyting". *Logic and Foundations of Mathematics. (Dedicated to Prof. A. Heyting on His 70th Birthday)* Groningen: Wolters-Noordhoff, 1968, 3–12. (Also published in *Compositio Mathematica* 20 (1968), 3–12.)

Traces Heyting's contributions to intuitionism, both as mathematics and as philosophy of mathematics. Includes a complete bibliography of his articles and books.

2398. Ulam, S. M. *Adventures of a Mathematician.* New York: Scribner's, 1976.

This semi-popular autobiography contains reminiscences of his early years at Łwow (as a prominent member of the Polish school), his years at Princeton and Harvard, his work on the atomic bomb at Los Alamos, and his return to academe at Boulder, Colorado. Photographs from throughout this period.

2399. Varadarajan, V. S. "Harish-Chandra, 1923–1983". *Journal of the Indian Mathematical Society* 56 (1–4) (1991), 190–215.

As compared with 2359, this article goes into more detail on the work of Harish-Chandra.

2400. Vonneumann, Nicholas A. *John von Neumann as Seen by His Brother*. Meadowbrook, PA: the author, 1987, 71 pp.

2401. Wang, Hao. *Reflections on Kurt Gödel*. Cambridge, MA: MIT Press, 1987, xxvi + 336 pp.

2402. Weil, André *The Apprenticeship of a Mathematician*. Basel: Birkhäuser, 1992, 197 pp.

An autobiographical account of Weil's early years. Originally published in French as *Souvenirs d'apprentissage* (1991). In 1947, Weil became a professor at the University of Chicago, and in 1958 he moved on to the Institute of Advanced Study in Princeton. He retired from the Institute in 1976. He died in 1998. The English edition has been reviewed at length by S. Mac Lane, *Bull. Amer. Math. Soc.* (N.S.) 28 (1993), no. 1, 144–147.

2403. Weingartner, Paul, and Leopold Schmetterer, eds. *Gödel Remembered: Salzburg 10–12 July 1983.* (History of Logic, No. 4.) Napoli: Bibliopolis, 1987, 186.

Contains a history of the Gödel family, reminiscences of Gödel, and some discussion of his mathematical logic.

2404. Whitehead, George W. "Norman Earl Steenrod, April 22, 1910–October 14, 1971". *Biographical Memoirs of Members of the National Academy of Sciences.* 55 (1985), 453–470.

2405. Zygmund, Antoni. "Stanislaw Saks, 1897–1942". *Mathematical Intelligencer* 9 (1) (1987), 36–41.

A tribute to a great Polish mathematician who perished in World War II, from one who survived.

Concepts and Disciplines

This does not include studies of the modern mathematical topics represented by separate sections of the bibliography.

2406. Arnold, Bernd J. "Das Kontinuitätsprogramm zwischen Cantor und der Nonstandard-analysis". *Historia Mathematica* 15 (1988), 250–263.

2407. Bennett, S. "The Emergence of a Discipline: Automatic Control, 1940–1960". *Automatica, the Journal of the International Federation of Automatic Control* 12 (2) (1976), 113–121.

This informal survey concentrates on people and institutions.

2408. Biggs, Norman L., E. Keith Lloyd, and Robin J. Wilson, eds. *Graph Theory 1736–1936*. Oxford: Clarendon, 1976. xi + 239 pp.

Thirty-seven extracts from publications on graph theory, together with brief historical commentary. Twelve of these are from the twentieth century, including works by H. Prüfer, G. Pólya, H. Tietze, O. Frink, O. Veblen, K. Kuratowski, H. Whitney, G. D. Birkhoff, and P. Franklin.

2409. Campbell, Paul J. "The Origin of 'Zorn's Lemma.'" *Historia Mathematica* 5 (1978), 77–89.

Discusses the development of maximal principles from F. Hausdorff (1907) to H. Kneser (1950). Includes excerpts from interviews with M. Zorn.

2410. Franczyk, B., and E. Körner. "Zur Intuitiv-geometrischen Entstehung der Ersten Universellen Katastrophenform nach Thom". *Wissenschaftliche Zeitschrift der Technischen Hochschule Ilmenau* 30 (4) (1984), 67–74.

An account of the origins of catastrophe theory.

2411. Harary, Frank. "On the History of the Theory of Graphs". *New Directions in the Theory of Graphs*. Edited by F. Harary. New York: Academic Press, 1973, 1–17.

A brief discussion of 12 major theorems concering graphs, eight of them in the twentieth century. See also his "The Explosive Growth of Graph Theory", *Annals of the New York Academy of Sciences* 328 (1979), 5–11, which takes a quantitative approach.

2412. Heims, Steve Joshua. *The Cybernetics Group*. Cambridge, MA: MIT Press, 1991, xiv + 334 pp.

A good general account of what cybernetics was intended to be at its inception in the mid-twentieth century.

2413. Kadvany, John. "Reflections on the Legacy of Kurt Gödel: Mathematics, Skepticism, Post Modernism". *Philosophical Forum* 20 (1989), 161–181.

2414. Lesort, Marc. "How Fractals Were Discovered". *Mathematics Education* 3 (4) (1987), 11–17.

An interview with Benoit Mandelbrot, containing some of his illuminating observations on his work.

2416. Mayer, Jean. "Le Théorème des Quatre Couleurs: Notice Historique et Aperçu Technique". *Cahiers du Seminaire d'Histoire des Mathématiques* 3 (1982), 43–62.

The author gives an account of the famous problem and its solution, taking particular care to expound the principle by which it was solved.

2417. Oelschlägel, Dieter. "Zur Geschichte der Mathematik: Entwicklungstendenzen der Numerischen Mathematik in unserem

Jahrhundert". *Wissenschaftliche Zeitschrift der Technischen Hochschule Leuna–Merseburg* 31 (2) (1989), 211–217.

This article is an attempt to evaluate the trends in numerical methods as reflected in journals of abstracts.

2418. Polak, Elijah. "An Historical Survey of Computational Methods in Optimal Control". *SIAM (Society for Industrial and Applied Mathematics) Review* 15 (1973), 553–584.

Discusses the development of optimal control algorithms from 1948 to 1973, with brief excursions into earlier work.

2419. Saaty, Thomas L., and Paul C. Xainen. *The Four-Color Problem: Assaults and Conquest.* New York: McGraw-Hill, 1977.

A detailed technical study of variants of the four-color problem from Francis Guthrie, who formulated the problem and conjectured the sufficiency of four colors in 1852, to the problem's solution by K. Appel and W. Haken in 1976. Limited historical analysis.

2420. Stachowicz, Marian S. "Theory of Fuzzy Sets and its Applications—a Retrospective". In Polish. *Postepy Cybernetyki* 9 (3) (1986), 5–15.

A nontechnical overview of the history of an area of mathematics that arose in the second half of the twentieth century.

2421. Steen, Lynn A. "Highlights in the History of Spectral Theory". *American Mathematical Monthly* 80 (1973), 359–381.

An overview of the spectral theorem in operator theory, as well as its roots in linear algebra and integral equations. Emphasizes the work of Hilbert and the central role of quantum mechanics. Concludes with the Gelfand-Naĭ mark theorem.

2422. Vanderplaats, G. N. "Structural Optimization—Past, Present, and Future". *American Institute of Aeronautics and Astronautics Journal* 20 (7) (1982), 992–1000.

This article gives an assessment of the current state of structural optimization theory, emphasizing numerical techniques.

2423. Wang, Paul P., Sam Earp, and Ruspini, Enrique II. "Fuzzy Set Theory: Past, Present, and Future". In *Advances in Fuzzy Sets, Possibility Theory, and Applications.* New York-London: Plenum Publishing Corporation, 1983. 1–11.

This chapter is the introduction to a reprinting of 24 basic articles in fuzzy set theory. It discusses the history of the area and current trends.

2424. Weintraub, E. Roy, ed. *Toward a History of Game Theory.* Durham, NC: Duke University Press, 1992, vi + 306 pp.

A collection of papers on the history of game theory, which arose during and just after World War II.

Communities

(Studies of Institutions and of National Traditions in Mathematics)

2425. Blakers, A. L. "The Australian Mathematical Society: Foundation and Early Years. II". *Australian Mathematical Society Gazette* 3 (3) (1976), 65–83.

The author traces the development of the Australian Mathematical Society from its inception in 1952 through its formal founding in 1956.

2426. Berger, Marcel. "French Mathematics Today". In Osmo Pekonen, ed. *In the Forest of Symbols*. In Finnish. Helsinki: Art House, 1992. 72–87.

A concise survey of mathematics as currently practiced in France.

2427. Brigaglia, Aldo. "Sur les Relations des Mathématiciens Français et Italiens au Début du XXe Siècle". *Cahiers du Séminaire d'Histoire des Mathématiques* 5 (1984), 21–49.

2428. Dauben, Joseph Warren. "Mathematicians and World War I: The International Diplomacy of G. H. Hardy and Gösta Mittag-Leffler as Reflected in Their Personal Correspondence". *Historia Mathematica* 7 (1980), 261–288.

Discusses the epistolary efforts of Hardy and Mittag-Leffler to achive a rapprochement between Allied and German mathematicians shortly after the First World War. Includes letters from that correspondence.

2429. Dieudonné, Jean. "The Work of Nicolas Bourbaki". *American Mathematical Monthly* 77 (1970), 134–145.

One of the founders of the polycephalic Bourbaki explains its origins, structure, and rules. Dieudonné describes how the loss of young French mathematicians during the First World War created a gap for those, such as himself, who came into mathematics soon afterward. J. Hadamard's seminar on analysis, led after 1934 by G. Julia, helped to fill this gap. Van der Waerden's *Moderne Algebra* stimulated the Bourbaki group to write their synopsis of mathematics.

2430. Fitzgerald, Anne, and Saunders Mac Lane, eds. *Pure and Applied Mathematics in the People's Republic of China: A Trip Report of the American Pure and Applied Mathematics Delegation*. Washington, D.C.: National Academy of Sciences, 1977.

Discusses sympathetically the role that mathematics has played in contemporary China, particularly since the Cultural Revolution. In particular, it considers the political goals of Chinese mathematicians, as well as the place of mathematics in research institutes and universities. Includes abstracts of several lectures given by Chinese mathematicians to the American delegation.

2431. Hupalowska, Danuta. “The Mathematical Works of the Warsaw School in the Years 1905–1918”. *Studia i Materialy z Dziejów Nauki Polskiej, Seriaa II* 2 (1989), 3–12.

2432. Israel, G., and L. Nurzia. “Fundamental Trends and Conflicts in Italian Mathematics between the two World Wars”. *Archive Internationale d’Histoire des Sciences* 39 (1989), 111–143.

2433. Kuratowski, Kazimierz. *A Half Century of Polish Mathematics: Remembrances and Reflections*. New York: Pergamon, 1980.

Not a detailed historical analysis but a series of reminiscences, this volume treats the development of Polish mathematics from 1920 to 1970. Both the Warsaw and Lwow schools are discussed, and brief biographies of nine of the leading mathematicians in those schools are given.

2434. Kuzawa, Mary Grace. *Modern Mathematics: The Genesis of a School in Poland*. New Haven: College and University Press, 1968.

Analyzes in detail (but somewhat uncritically) the forces that led to the flowering of the Polish school of mathematics under W. Sierpiński between the two world wars. Contains a translation from Polish of Z. Janiszewski’s seminal article “The Needs of Mathematics in Poland,” which helped to stimulate the founding of the school and of the journal *Fundamenta Mathematicae*.

2435. Mikolás, M. “Some Historical Aspects of the Development of Mathematical Analysis in Hungary”. *Historia Mathematica* 2 (1975), 304–308.

Discusses the factors that led to the flowering of Hungarian mathematics in the twentieth century.

2436. Muczyk, Jan P. “The Polish School of Mathematics”. *East European Quarterly* 27 (1993), 231–242.

A description of advances made at Polish universities between the two world wars.

2437. Pawlikowska-Brozek, Zofia. “Polish Mathematics in the Years 1918–1951” In ln Polish. *Studia i Materialy z Dziejów Nauki Polskiej, Seria II* 2 (1989), 13–59.

2438. Pekonen, Osmo “Encounters with Vietnamese Mathematicians”. *Arkhimedes* 45 (2) (1993), 178–186.

An account of Vietnamese mathematics based on a visit by the author in 1993, pointing out an interesting historical connection between Finnish and Vietnamese mathematics.

2439. Rowe, David. "Klein, Hilbert, and the Göttingen Mathematical Tradition". *Osiris* (2nd series) 5 (1989), 186–213.

A detailed and very readable account of the mathematical tradition of one of the outstanding mathematical centers of the early twentieth century.

2440. Siegmund-Schultze, Reinhard. "Hilda Geiringer-von Mises, Charlier Series, ideology, and the Human Side of the Emancipation of Applied Mathematics at the University of Berlin during the 1920s". *Historia Mathematica* 20 (1993), 364–381.

The title is a succinct summary of the contents of the article itself.

2441. Toti Rigatelli, Laura. "Contributi Italiani della Prima Metà del XX Secolo alla Teoria de Galois". In Sergei S. Demidov, ed. *Amphora: Festschrift für Hans Wussing.* Basel: Birkhäuser, 1992. 773–780.

2442. Tropp, Henry S. "The Origins and History of the Fields Medal". *Historia Mathematica* 3 (1976), 167–181.

A study of J. C. Fields and the committee that established the Fields Medal in 1936. Lists the recipients of the medal through 1974. For more recent recipients, see the brief articles in *Science* 202 (1978), 297–298, 505–506, 612–613, 737–739.

V. THE HISTORY OF MATHEMATICS: SUB-DISCIPLINES

The following section of this annotated bibliography divides the history of mathematics into a number of specific categories. Not all are exclusive, and there is from time to time unavoidable overlapping with earlier sections of the bibliography, although cross-referencing has been used to avoid needless repetition. Where items appear that have been annotated previously, comments are limited to remarks appropriate to the specific category in question. For the most part, general reference works, periodicals, and other non-specialized materials have not been listed here, except for items of very specific relevance.

ALGEBRA

Theory of Equations (Classical Algebra)

2443. Ayoub, Raymond G. "Paolo Ruffini's Contributions to the Quintic". *Archive for History of Exact Sciences* 23 (1980), 253-277.

Gives an analysis (in modern notation) of Ruffini's various proofs of the unsolvability of the general polynomial of degree 5, and comments on their lack of acceptance by the mathematical community at large.

2444. Bartolozzi, Margherita, and Raffaella Franci. "La regola dei segni dall'enunciato di R. Descartes (1637) alla dimostrazione di C. F. Gauss (1828)". *Archive for History of Exact Sciences* 45 (1992-93), 335-374.

A history of Descartes's famous Rule of Signs, documenting subsequent work by figures such as Segner, De Gua, Kästner, Waring, Ruffini and Fourier, closing with Gauss's proof of 1828.

2445. Cajori, Florian. "Algebra in Napier's Days and Alleged Prior Inventions of Logarithms". In *Napier Tercentenary Memorial Volume*. Edited by C. G. Knott. Edinburgh, 1915, 93–109.

The paper discusses the situation of algebra in Napier's days with regard to the invention of logarithms.

2446. Day, M. S. *Scheubel as an Algebraist. Being a Study of Algebra in the Middle of the Sixteenth Century, Together with a Translation of and a Commentary upon an Unpublished Manuscript of Scheubel's Now in the Library of Columbia University.* New York: Teachers College, Columbia University, 1926.

The first part gives a brief survey of the general status of algebra before the sixteenth century, the contributions of the sixteenth century before Scheubel's time, as well as Scheubel's life, works, and influence.

2447. Gårding, Lars, and Christian Skau. "Niels Henrik Abel and Solvable Equations". *Archive for History of Exact Sciences* 48 (1994), 81-103.

An analysis of an unpublished manuscript by Abel of 1828, in the light of modernized versions and extensions of his proofs, which shows that he had a complete description of the roots of a solvable equation of prime degree (a result later ascribed to Kronecker and Weber).

2448. Gilain, Christian. “Sur l’histoire du théorème fondamental de l’algèbre: théorie des équations et calcul intégral”. *Archive for History of Exact Sciences* 42 (1991), 91-136.

A study of the chief events in the story of the Fundamental Theorem of Algebra, from its first statement by Girard in 1629. Concentrates on 18th-century work, principally by Euler and d’Alembert.

2449. Gilain, Christian. “Le théorème fondamental de l’algèbre et la théorie géométrique des nombres complexes au XIXe siècle”. In Dominique Flament, ed. *Le nombre: une hydre à n visages: Entre nombres complexes et vecteurs*. Paris: Éditions de la Maison des sciences de l’homme, 1997, 51-73.

A study of early-19th-century work (mainly French) on the then new geometrical theory of complex numbers. This paper focuses on its relation to the history of the Fundamental Theorem of Algebra, as well as the role played by the theorem in the establishment of the new theory.

2450. Hamburg, Robin Rider “The Theory of Equations in the 18th Century: The Work of Joseph Lagrange”. *Archive for History of Exact Sciences* 16 (1976/1977), 17–36.

Covers both the development of Lagrange’s ideas on algebraic solvability of polynomial equations in connection with symmetric functions and his analytic work on numerical solutions. Argues that the analytic work did not lead to a unified theory whereas the algebraic work was momentous for the later development of group theory.

2451. Hoe, John. *Les systèmes d’équations polynômes dans le Sìyúan Yùjiàn (1303)*. Mémoirs de l’Institut des Hautés Etudes Chinoises. Paris: Collège de France, Institut des Hautes Etudes Chinoises, 1977, 341 pp.

Hoe’s aim is to appreciate the contributions of China to mathematics. The eighth chapter, “Jade Mirror of the Four Unknowns: Sìyúan yùjiàn,” is consecrated to the solution of systems of linear equations by way of reducing the coefficient matrix to a triangular form. See also item 4444.

2452. Huber, Englebert. “Historische Entwicklung von Näherungsverfahren zur Lösung algebraischer Gleichungen”. Dissertation der Ludwig-Maximilians-Universität, Munich, 1978, 121 pp.

The author collects all methods which have appeared in the history of mathematics and classifies them according to underlying principles. He analyzes the development of the theory up to the beginning of the nineteenth century. Extensive bibliography of primary sources.

2453. Karpinski, Louis C. “An Italian Algebra of the Fifteenth Century”. *Bibliotheca Mathematica* 11 (1910/1911), 209–219.

Guglielmo de Lunis’s algebraical achievements are investigated by means of discussing a manuscript of 1464.

2454. Kaunzner, Wolfgang. “Über einen frühen Nachweis zur symbolischen Algebra”. *Österreichische Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Klasse, Denkschriften (Vienna)*, Vol. 116, Part 5 (1975), 3–12 + ii.

The author shows that the medieval manuscripts Vat. lat. 4606 and Lyell 52 (Oxford), depending on an unknown source, contain early proofs of symbolical algebra. See also item 1821.

2455. Kaunzner, Wolfgang. “Über die Entwicklung der algebraischen Symbolik vor Kepler im deutschen Sprachgebiet”. In *Kepler–Festschrift 1971*. Munich: Mittelbayerische Druckerei- und Verlags-Gesellschaft, 1972, 175–185.

The author proves that modern algebraic notation depends with regard to several points on German mathematicians who lived in the fifteenth and sixteenth centuries in southern Germany.

2456. Kaunzner, Wolfgang. “Über das Zusammenwirken von Systematik und Problematik in der frühen deutschen Algebra”. *Sudhoffs Archiv* 54 (1970), 299–315.

The paper appreciates some mathematical achievements of the late middle ages (1460–1550). The methods of solving algebraic equations arose from a rather low level to a level never attained before. This progress culminated in an almost complete symbolization of equations of degree one, two, and reducible higher equations.

2457. Knobloch, Eberhard. “Unbekannte Studien von Leibniz sur Eliminations- und Explikationstheorie”. *Archive for History of Exact Sciences* 12 (1974), 142–173.

A discussion of Leibniz’s most important manuscripts which are concerned with elimination theory. Most of these manuscripts are published in Eberhard Knobloch, *Der Beginn der Determinantentheorie, Leibnizens nachgelassene Studien zum Determinantenkalkül* (Textband, Arbor scientiarum Reihe B, Bd. 2, Hildesheim: Gerstenberg, 1980), xi + 332 pp.

2458. Nesselmann, Georg Heinrich Ferdinand. *Versuch einer kritischen Geschichte der Algebra I. Die Algebra der Griechen*. Berlin: G. Reimer, 1842. Reprinted Frankfurt: Minerva, 1969.

This partly antiquated book gives a survey of Greek algebraic achievements.

2459. Rashed, Roshdi. "Résolution des équations numériques et algèbre: Šaraf-al-Dīn al-Ṭūsī, Viète". *Archive for History of Exact Sciences* 12 (1974), 244–290.

The paper's aim is to prove two theses: the work of al-Ṭūsī, concerned with numerical equations and decimal fractions, is the result of a renovation begun by the algebraists of the eleventh and twelfth centuries. Al-Ṭūsī possessed a method which Viète's method essentially followed.

2460. Rosen, Michael I. "Niels Henrik Abel and Equations of the Fifth Degree". *American Mathematical Monthly* 102 (1995), 495-505.

An account, in modern mathematical language, of how Abel proved the unsolvability of the general quintic in 1824, without the use of the later Galois theory.

2461. Sanford, Vera. *The History and Significance of Certain Standard Problems in Algebra*. New York: Teachers College, Columbia University, 1927.

The book contains a collection and historical analysis of the mathematical literature, especially of the Middle Ages and Renaissance, as far as certain problems of daily life and recreation literature are concerned. Also published by Teachers College, Columbia University as *Contributions to Education*, No. 251 (1927).

2462. Scriba, Christoph J. "Zur Entwicklung und Verbreitung der Algebra im 17. Jahrhundert". *Mededelingen uit het Seminarie voor geschiedenis van de Wiskunde en de Natuurwetenschappen aan de katholieke Universiteit de Leuven* 4 (1971), 13–22.

The article gives an outline of the development and propagation of algebra in the 16th and 17th centuries (Italian school, Stifel, Wallis).

2463. Spiesser, M. "La résolution numérique des équations dans l'histoire des mathématiques chinoises jusqu'au XIVème siècle". *Séminaire d'Histoire des Mathématiques de Toulouse* (Cahiers No. 4), (1982), 77–98.

2464. Tropfke, Johannes. *Geschichte der Elementarmathematik*. Bd. 1. *Arithmetik und Algebra*. Bearbeitet von Kurt Vogel, Karin Reich, Helmuth Gericke. Kapitel 3: Algebra. Berlin; New York: Walter de Gruyter, 1980, 742 pp.

The third chapter (pp. 359–511) deals with the development of algebraic thinking and procedures (the art of finding unknown quantities by means of known quantities) from the Egyptians up to the proof of the fundamental theorem by Gauss. Very useful bibliography. See also items 1669 and 1893.

2465. Toti Rigatelli, Laura. "The Theory of Equations from Cardano to Galois, 1540-1830". In Ivor Grattan-Guinness, ed., *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. New York: Routledge, 1994, 713-721.

A good introductory overview of the development of the theory of equations up to Galois, with a nice selection of further reading on the history of the subject.

2466. Viète, François. *Einführung in die neue Algebra*. Übersetzt und erläutert von Karin Reich, Helmuth Gericke. Munich: Werner Fritsch, 1973, 145 pp.

The book contains an extensive introduction to the prehistory of reckoning by means of letters and to Viète's algebraic works. See also item 2066.

2467. Vogel, Kurt. "Zur Geschichte der linearen Gleichungen mit mehreren Unbekannten". *Deutsche Mathematik* 5 (1940), 217–240.

The article deals with the fifth part of the twelfth chapter of Leonardo's *Liber abaci* where many problems are solved algebraically.

2468. Vogel, Kurt. "Die Algebra der Ägypter des mittleren Reiches". *Archeion* 12 (1930), 126–162.

The article discusses the algebraical achievements of the Egyptians of the middle empire.

2469. Wappler, Hermann Emil. "Zur Geschichte der deutschen Algebra". *Abhandlungen zur Geschichte der Mathematik* 9 (1899), 537–554.

The article analyzes a German algebra of 1481 (*codex Dresdensi* C 80) together with additional remarks of Johann Widmann of Eger.

2470. Wappler, Hermann Emil. "Zur Geschichte der deutschen Algebra im 15. Jahrhundert". *Programm des Gymnasiums Zwickau 1886/7*. Zwickau, 1887.

This work investigates some major contributions to algebra by German mathematicians of the 15th century.

Algebraic Structures (Modern, Abstract Algebra)

2471. Bašmakova, Isabella G. "Sur l'histoire de l'algèbre commutative". *Revue de Synthèse* 89 (1968), 185–202.

The paper investigates the two sources of commtutative algebra: the theory of divisibility (from antiquity to the 19th century) and the reciprocal influence of the theory of algebraic numbers and algebraic functions.

2472. Becher, Harvey W. "Woodhouse, Babbage, Peacock, and Modern Algebra". *Historia Mathematica* 7 (1980), 389-400.

A response to Dubbey, item 2485, this paper argues that the innovative aspects of the published algebraic system of George Peacock (1830) and an unpublished work by Charles Babbage (1821) are extensions of earlier ideas by their elder Cambridge contemporary Robert Woodhouse.

2473. Birkeland, Bent. "Ludvig Sylow's Lectures on Algebraic Equations and Substitutions, Christiania (Oslo), 1862: an Introduction and a Summary". *Historia Mathematica* 23 (1996), 182-199.

This article surveys the notes (recently published in Norwegian) written by Ludvig Sylow (1832-1918) for a course he gave on Galois theory at the University of Oslo in 1862-63. Apart from the fact that this course represented Sophus Lie's first introduction to the theory of groups, these notes are significant because they reveal that Sylow was already posing himself the problem which was to lead him to the famous "Sylow theorems" on the existence of subgroups of a given order in a finite group (published in 1872).

2474. Birkhoff, Garrett. "Current Trends in Algebra". *The American Mathematical Monthly* 80 (1973), 760–782.

Survey of the development of modern algebra up to World War I, and especially the reign of modern algebra between 1930 and 1970.

2475. Burkhardt, Heinrich. "Die Anfänge der Gruppentheorie und Paolo Ruffini". *Abhandlungen zur Geschichte der Mathematik. Heft 6.* Leipzig: B. G. Teubner, 1892, 119–159.

The article investigates the development of the ideas underlying Ruffini's papers which are concerned with group theory (theory of substitutions). It stresses the importance of Ruffini in spite of Cauchy's achievements.

2476. Chandler, Bruce, and Wilhelm Magnus. *The History of Combinatorial Group Theory: A Case Study in the History of Ideas.* New York, Berlin: Springer-Verlag, 1982.

A two-part history of the development of combinatorial group theory. The first deals with the origins of the subject from 1882 to 1918. The second covers the the time from 1918 to 1945, when the subject emerged as a independent area of study. The mathematical discussions are supplemented with sections on modes of communication and dissemination of this research, as well as biographical notes. There is also a superb bibliography.

2477. Coleman, A. John. "The Greatest Mathematical Paper of All Time". *The Mathematical Intelligencer* 11 (3) (1989), 29-38.

Whatever one may think of its title, this is a well-informed and highly readable article, which argues that Wilhelm Killing's second 1888 paper on Lie algebras (entitled "Die Zusammensetzung der stetigen, endlichen Transformationsgruppen") marked an epoch in the history of the classification of mathematical structures.

2478. Corry, Leo. *Modern Algebra and the Rise of Mathematical Structures.* Basel, Boston: Birkhäuser Verlag, 1996.

This work describes the development of mathematical structures in two stages. The first analyses the transformation of the algebraic discipline into the study of structures, by concentrating on developments within the theory of ideals from Dedekind to Emmy Noether and ultimately van der Waerden's *Moderne Algebra* of 1930. The second section examines the deeper question of the place of structures within mathematics via historical treatments of the lattice theory of Øystein Ore the structure theory of Nicolas Bourbaki and the theory of categories and functors. Extensive bibliography.

2479. Coutinho, S. C. "the Many Avatars of a Simple Algebra". *American Mathematical Monthly* 104 (1997), 593-604.

Here the so-called Weyl algebra, born in the 1920s cradle of quantum theory from work of Heisenberg, Born and C. Jordan, is presented as an example of a mathematical structure showing up in different contexts under different guises.

2480. Crowe, Michael J. *A History of Vector Analysis: The Evolution of the Idea of a Vectorial System.* New York: Dover, 1985. Reprint of 1967 edition with corrections and new bibliographical preface.

Noteworthy history of vector algebra. Concentrates on 3-dimensional vectorial systems. Traces development from the geometrical representation of complex numbers to W. R. Hamilton's discovery of the quaternions to the physical application of quaternions by Tait and (to a limited extent) Maxwell to the construction of a modern system of vectors by Gibbs and Heaviside. Argues that the latter two "forged modern vector analysis from quaternion (not Grassmannian) elements." Features insightful chapters on Hamilton and H. Grassmann, and statistical analysis of comparative reception of their work. This valuable book is based on extensive research into primary and secondary sources. Absence of a bibliography is compensated for by especially rich footnotes. Footnote format has been criticized as awkward and inconvenient.

2481. Curtis, Charles W. "Representation Theory of Finite Groups: from Frobenius to Brauer". *The Mathematical Intelligencer* 14 (4) (1992), 48-57.

An account of some of the early work on the representation theory of finite groups. Beginning with the work of Frobenius from 1896 (prompted by Dedekind's research into the factorization of the group determinant of a finite abelian group), the article surveys subsequent work in this area by William Burnside Issai Schur and Emmy Noether concluding with the development of Richard Brauer's theory of modular representations.

2482. Dahan, Amy. "Les travaux de Cauchy sur les substitutions. Étude de son approche du concept de groupe". *Archive for History of Exact Sciences* 23 (1980), 279-319.

A study of Cauchy's work on substitutions. Beginning with his important memoirs of 1815, it examines the effect of work on solvability of equations by radicals, and especially the work of Galois, on Cauchy's subsequent work on substitutions between 1844 and 1846. It also comments on his influence on later mathematicians, such as Cayley, Serret and Jordan.

2483. Dieudonné, Jean. "Le développement historique de la notion de groupe". *Bulletin de la Société Mathematique de Belgique* 28 (1976), 267–296.

2484. Dieudonné, Jean. "The Difficult Birth of Mathematical Structures (1840–1940)". In *Scientific Culture in the Contemporary World*. Edited by V. Mathieu and P. Rosi. Milan: Scientia, in cooperation with UNESCO, 1970.

These articles trace the slow evolution of the idea of calculating on abstract objects, typically equivalence classes of better known objects (such as quadratic forms, classes modulo an ideal, or loops) from eighteenth-century origins in the theory of numbers and the theory of equations to modern mathematics. Dieudonné stresses the unity of mathematics which has thereby been achieved during a period of very rapid growth.

2485. Dubbey, John M. "Babbage, Peacock and Modern Algebra". *Historia Mathematica* 4 (1977), 295–302.

The paper discusses the ideas of Babbage and Peacock insofar as they initiated modern algebra in England.

2486. Dubbey, John M. *The Mathematical Work of Charles Babbage*. Cambridge: Cambridge University Press, 1978, 235 pp.

Pioneer study. Chapter 4 covers Babbage's invention of the calculus of functions. Chapter 5 explores and tries to account for the similarities between Babbage's unpublished "Philosophy of Analysis" of the early

1820s and Peacock's *Treatise on Algebra* of 1830. Considerable duplication between Chapter 5 and Dubbey, item 2485; but the former offers a more elaborate description of "The Philosophy of Analysis." See also item 2309.

2487. Dubreil, Paul. "La naissance de deux jumelles: La logique mathématique et l'algèbre ordonnée". *Revue de Synthèse* 89 (1968), 203–209.

The paper gives an outline of the history of the development of mathematical logic and ordered algebra from Leibniz to G. Boole (middle of the 19th century).

2488. Dubreil, Paul. "Apparition et Premiers Développements de la Théorie des Demi-groupes en France". *Cahiers du Séminaire d'Histoire des Mathématiques* 2 (1981), 59–65.

The author gives the point of view of a personal participant on the rise of the theory of semigroups in France during the late twentieth century.

2489. Dubreil, Paul. "L'algèbre en France, de 1900 à 1935". *Cahiers du Sëminaire d'Histoire des Mathématiques* 3 (1982), 69–81.

2490. Edwards, Harold M. *Galois Theory.* New York: Springer-Verlag, 1984.

More of a mathematical than a historical exposition, this is an extremely clear and lucid presentation of Galois theory "in terms close enough to Galois's own to make his memoir accessible to the reader". Beginning with the work of predecessors such as Newton, Lagrange and Gauss on the theory of equations, Edwards develops the work of Galois in the style of his time, but gives thorough and carefully explained proofs of all the results.

2491. Fenster, Della Dumbaugh. "Leonard Eugene Dickson and His Work in the Arithmetics of Algebras". *Archive for History of Exact Sciences* 52 (1998), 119-159.

This paper focuses on the history of the arithmetics of algebras, via the work of Lipschitz, Hurwitz, and the little-known Gustave du Pasquier before highlighting Dickson's important contributions to the subject in the 1920s.

2492. Freudenthal, Hans. "L'algèbre topologique en particulier les groupes topologiques et de Lie". *Revue de Synthèse* 89 (1968), 223–243.

The paper gives an outline of the development of topological algebra from 1888 (Cayley) to 1957 (Freudenthal). It is especially concerned with Lie's achievements in group theory and the divorce and later reunion of algebra and topology.

2493. Hamilton, William Rowan. *The Mathematical Papers of Sir William Rowan Hamilton.* Vol. 3: *Algebra.* Edited by H. Halberstam, and R. E. Ingram. Cambridge: Cambridge University Press, 1967.

Judiciously compiled sampler of Hamilton's algebraic writings. Divided into four parts. Part 1 features the famous essay of 1837 on complex numbers as number-couples and on algebra as the science of pure time. The selections of part 2 cover the discovery, development, and application (to geometry and mechanics) of the quaternions. Part 3 deals with algebraic equations and includes Hamilton's account (with corrections) of Abel's proof of the insolubility of the general quintic. The only section offering substantial hitherto-unpublished material, part 4 introduces Hamilton's reflections on the icosian calculus. The primary material is supplemented by the editors' introduction, footnotes, and appendices clarifying mathematical and historical points.

2494. Harkin, Duncan. "The Development of Modern Algebra". *Norsk matematisk Tidsskrift* 33 (1951), 17–26.

The paper contains some general ideas with regard to the development of modern algebra and discusses mainly Hamilton's couples and Benjamin Peirce's *Linear Associative Algebra.*

2495. Hasse, Helmut. "Geschichte der Klassenkörpertheorie". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 68 (1966), 166–181.

Discussion of the history of class field theory from 1853 (Kronecker) up to 1940 (Hilbert). Bibliography of the primary literature.

2496. Hawkins, Thomas. "Hypercomplex Numbers, Lie Groups, and the Creation of Group Representation Theory". *Archive for History of Exact Sciences* 8 (1971/1972), 243–287.

The paper investigates the history of hypercomplex numbers, matrices, and Lie groups, the structure theorems of Molien and E. Cartan, group algebra and group representation, and Maschke's discovery of complete reducibility. Extensive bibliography.

2497. Hawkins, Thomas. "The Creation of the Theory of Group Characters". In *History of Analysis.* Edited by R. J. Stanton and R. O. Wells. (Rice University Studies 64, Nos. 2, 3.) Houston, Tex.: William Marsh Rice University, 1978, 57–71.

Traces in detail Frobenius's route to his discovery of the theory of characters and group representations, drawing on the extensive Dedekind-Frobenius correspondence.

2498. Hawkins, Thomas. "The Theory of Matrices in the 19th Century". *Proceedings of the International Congress of Mathematicians.* Vol. 2.

Edited by R. D. James. Vancouver: Canadian Mathematical Congress, 1975, 561–570.

See item 2501.

2499. Hawkins, Thomas. "Weierstrass and the Theory of Matrices". *Archive for History of Exact Sciences* 17 (1977), 119–163.

See item 2501.

2500. Hawkins, Thomas. "Another Look at Cayley and the Theory of Matrices". *Archives Internationales d'Histoire des Sciences* 26:100 (1977), 82–112.

See item 2501.

2501. Hawkins, Thomas. "Cauchy and the Spectral Theory of Matrices". *Historia Mathematica* 2 (1975), 1–29.

In items 2498, 2499, 2500, and 1026, Hawkins argues for the central importance in the development of the spectral theory of matrices of the work of Weierstrass. The general theory of simultaneous diagonalization of two quadratic forms in n variables, with particular attention to special cases, is shown to be characteristic of the Berlin school (Weierstrass, Kronecker, Frobenius). Origins of the theory of matrices in the work of Gauss, Eisenstein, Cauchy, Hermite, and Cayley are discussed, with examples taken from number theory, differential equations, and quadratic forms.

2502. Hawkins, Thomas. "Non-Euclidean Geometry and Weierstrassian Mathematics: the Background to Killing's Work on Lie Algebras". *Historia Mathematica* 7 (1980), 289-342.

A detailed analysis of the influence of results in non-Euclidean geometry and the approach of Weierstrass on Wilhelm Killing's research into the foundations of geometry, and ultimately to his work on the structure of Lie algebras.

2503. Hawkins, Thomas. "Wilhelm Killing and the Structure of Lie Algebras". *Archive for History of Exact Sciences* 26 (1982), 127-192.

A substantial discussion of how Killing's research on the foundations of geometry led to fundamental ideas underlying the structure of Lie algebras. Use is made of the Killing–F. Engel correspondence to show how Killing related his ideas to Lie's theory of transformation groups. Finally, the paper deals with E. Cartan's assimilation of Killing's work into what is essentially its modern form. Closes with a list of unpublished material and a thorough bibliography.

2504. Hawkins, Thomas. "Jacobi and the Birth of Lie's Theory of Groups". *Archive for History of Exact Sciences* 42 (1991), 187-278.

An evaluation of the influence of C. G. Jacobi's work on partial differential equations on Sophus Lie and how it affected Lie's creation of a theory of continuous groups.

2505. Itard, Jean. "La théorie des nombres et les origines de l'algèbre moderne". *Revue de Synthèse* 89 (1968), 165–184.

The article investigates the theory of numbers as one of the many origins of modern algebra, beginning with Euclid, Books VII, VIII, IX, and ending with the middle of the nineteenth century (Kummer's ideal numbers).

2506. Keotsier, Teun. "Explanation in the Historiography of Mathematics: the Case of Hamilton's Quaternions". *Studies in the History and Philosophy of Science* 26 (1995), 593-616.

Hamilton's discovery of quaternions in 1843 has been studied by historians from several perspectives. This study of Hamilton's mathematical acts uses W. H. Dray's 1957 model for historical explanation. It concludes that Hamilton's breakthrough arose from the symbolic approach, distinguished from a geometrical and a foundational approach.

2507. Kiernan, B. M. "The Development of Galois' Theory from Lagrange to Artin". *Archive for History of Exact Sciences* 8 (1971/1972), 40–154.

Kiernan considers the study of the solvability of polynomial equations by Lagrange, Ruffini, Gauss, Cauchy, Abel, and Galois; traces the development of Galois's ideas in France (Serret and C. Jordan) as abstract group theory, and in Germany (Kronecker, Dedekind, H. Weber) as field theory; his discussion ends with Emil Artin.

2508. Lewis, Albert C. "Complex Numbers and Vector Algebra". In Ivor Grattan-Guinness, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* New York: Routledge, 1994, 722-729.

Informative introduction to the history of the algebra of complex numbers to the end of the nineteenth century, including sections on geometric representation, generalization, and vector algebra.

2509. Mac Lane, Saunders. "Origins of the Cohomology of Groups". *L'Enseignement Mathématique*, Série 2, 24 (1978), 1–29.

Essay on the development of a part of contemporary mathematics: origin of the theory of the cohomology of groups, essential steps in its development, effects of this development in related fields of mathematics (for example, spectral sequences). Useful bibliography.

2510. May, Kenneth O. "The Impossibility of a Division Algebra of Vectors in Three Dimensional Space". *American Mathematical Monthly* 73 (1966), 289–291.

Oft-cited outline of work on the number of possible division algebras over the reals. Covers the period from Gauss through Bott and Milnor. Ends with a simple demonstration of the impossibility of a 3-dimensional division algebra over the reals. Useful basic bibliography.

2511. Mehrtens, Herbert. *Die Entstehung der Verbandstheorie.* (Arbor scientiarum, Reihe A, Bd. 6.) Hildesheim: Gerstenberg, 1979, 363 pp.

The book is concerned with the history of lattice theory from the middle of the 19th century up to 1940. The author understands the development of a (mathematical) theory as a social process. Extensive bibliography.

2512. Merzbach, Uta. "Development of Modern Algebraic Structures from Leibniz to Dedekind". Dissertation, Harvard University, 1964, 183 pp.

The dissertation discusses the origins of some of the concepts which characterize twentieth-century algebra and the close relationship between today's abstract algebra and the classical algebra which is concerned with real polynomials. It deals especially with Peacock's symbolical algebra, G. Boole's work on the algebra of logic, the axiomatic approach of Dedekind in developing his theory of ideals, and the historic basis of Dedekind's work. Useful bibliography of primary and secondary literature.

2513. Miller, George Abram. "History of the Theory of Groups to 1900". In *The Collected Works.* Urbana: University of Illinois, 1935–1938. 2 vols., here Vol. 1, 427–467.

The article gives an outline of the main developments in group theory up to 1900, beginning with developments antedating the beginning of the nineteenth century.

2514. Miller, George Abram. "Note on the History of Group Theory during the Period Covered by This Volume". *The Collected Works.* Urbana: University of Illinois, 1935–1938. 2 vols., here Vol. 2, 1–18.

Description of the development of group theory during the first decade of the twentieth century.

2515. Neumann, Olaf. "Die Entwicklung der Galois-Theorie zwischen Arithmetick und Topologie (1850 bis 1960)". *Archive for History of Exact Sciences* 50 (1996-97), 291-329.

A sketch of the development of Galois theory over a period of just over a century, in which the author shows its interconnection with topics such as function theory and algebraic topology. Impressive bibliography.

2516. Nicholson, Julia. "The Development and Understanding of the Concept of Quotient Group". *Historia Mathematica* 20 (1993), 68-88.

This paper describes the discovery and development of the concept of quotient group during the 19th century, and examines possible reasons for this development. The contributions of seven mathematicians in particular are discussed: Galois, Betti, C. Jordan, Dedekind, Dyck, Frobenius, and Hölder. The important link between the development of this concept and the abstraction of group theory is also considered.

2517. Nový, Luboš. *Origins of Modern Algebra.* Prague: Academia Publishing House of the Czechoslovak Academy of Sciences, 1973, 252 pp.

The book is concerned with the evolution of algebra between 1770 and 1870. This period is considered as one of the important stages in the development of modern algebra. Its aim is not to present an exhaustive history of algebra in the period considered but to discover, to illustrate, and to discuss trends in the evolution of algebra. Very extensive bibliography of the primary and secondary literature.

2518. Nový, Luboš. "L'école algébrique anglaise". *Revue de Synthèse* 89 (1968), 211–222.

The efforts of the members of the Cambridge analytical society in the beginning of the nineteenth century to create a new conception of algebra are discussed.

2519. Parshall, Karen Hunger. "Joseph H. M. Wedderburn and the Structure Theory of Algebras". *Archive for History of Exact Sciences* 32 (1985), 223-349.

Exhaustive study of the ground-breaking work by Wedderburn (1882-1948) on hypercomplex numbers, in the light of three pre-existing algebraic approaches: the "Anglo-American tradition" of Hamilton,Cayley, Sylvester and Peirce; the "Lie-Theoretic" school of Study, Scheffers and Molien; and the approach of Élie Cartan. Substantial bibliography.

2520. Parshall, Karen Hunger. "In Pursuit of the Finite Division Algebra Theorem and Beyond: Joseph H. M. Wedderburn, Leonard E. Dickson and Oswald Veblen". *Archives Internationales d'Histoire des Sciences* 33 (1983), 274-299.

This paper traces the development of the finite division algebra theorem by Wedderburn and Dickson, and the subsequent realization that this purely algebraic result had immediate applicability in projective geometry.

2521. Purkert, Walter. "Zur Genesis des abstrakten Körperbegriffs. Teil 1." *NTM-Schriftenreihe für die Geschichte der Naturwissenschaften,* *Technik und Medizin* 10 (1) (1973), 23–37; "Zur Genesis des abstrakten Körperbegriffs". Teil 2. 10 (2) (1973), 8–20.

The paper investigates the two roots of the field concept (theory of algebraic equations and algebraic number theory). It ends with an article of Steinitz, published in 1930, when the development of the theory of commutative fields came to a relative end.

2522. Purkert, Walter. "Ein Manuskript Dedekinds über Galois-Theorie". *NTM-Schriftenreihe für die Geschichte der Naturwissenschaften, Technik und Medizin*, Series 2, 13 (1976), 1–16.

Purkert has more information on Dedekind than does Kiernan, item 2507.

2523. Purkert, Walter, and Hans Wussing. "Fundamental Concepts of Abstract Algebra". In Ivor Grattan-Guinness, ed., *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, New York: Routledge, 1994, 741-760.

This article deals with the history of the basic algebraic concepts that had evolved by the end of the nineteenth century as the first axiomatically defined mathematical structures. Its three sections cover groups; fields, rings and ideals; and other structures including lattices and categories. Excellent bibliography.

2524. Pycior, Helena M. "Benjamin Peirce's *Linear Associative Algebra*". *Isis* 70 (1979), 537–551.

Study of the context, content, and significance of Peirce's *Linear Associative Algebra* of 1870. Explores the relationship between this work and that of such early 19th-century British algebraists as Peacock, De Morgan, and W. R. Hamilton. Argues that Peirce's acceptance and extension of the symbolical approach to algebra were facilitated by his theological belief in a correspondence between human ideas and the physical universe.

2525. Pycior, Helena M. "The Role of Sir William Rowan Hamilton in the Development of British Modern Algebra". Dissertation, Cornell University, 1976.

Partial mathematical biography of Hamilton, emphasizing 1828 through 1851. Discusses dominant trends in British algebra of the late 18th and early 19th centuries. Investigates Hamilton's relationship with the symbolical algebraists, principally Peacock and De Morgan, and the connections among Hamilton's mathematics, philosophy, and poetry. Uses some of Hamilton's unpublished manuscripts. Noteworthy bibliography.

2526. Pycior, Helena M. "the Philosophy of Algebra". In Ivor Grattan-Guinness, ed. *Companion Encyclopedia of the History* *and Philosophy of the Mathematical Sciences*. New York: Routledge, 1994, 794-805.

A solid survey of the underlying attitudes to algebra between the sixteenth and nineteenth centuries, from uncertainties over negative and imaginary numbers to the growth of abstraction in the nineeteenth century.

2527. Scharlau, Winfried. "Unveröffentlichte algebraische Arbeiten Richard Dedekind aus seiner Göttinger Zeit 1855-1858". *Archive for History of Exact Sciences* 27 (1982), 335-367.

A study of Dedekind's work on higher algebra and Galois theory during his years as a privatdozent at Göttingen.

2528. Scharlau, Winfried. "Die Entdeckung der Sylow-Sätze". *Historia Mathematica* 15 (1988), 40-52.

This paper describes Sylow's discovery of his eponymous theorems from his study of Galois's criterion for the solvability of equations of prime degree. It also makes use of his correspondence on the subject with C. Jordan and Petersen.

2529. Sinaceur, Hourya. *Corps et modèles: essai sur l'histoire de l'algèbre réelle*. Paris: Libraire Philosophique J. Vrin, 1991.

A work of considerable range and depth, investigating the influence of Sturm's theorem (1829) on later notable developments, particularly the abstract ideal theory of Emil Artin and Schreier Otto, the mathematical logic of Tarski and the model theory of Robinson. An interesting new perspective.

2530. Sinègre, Luc. "Les quaternions et la movement du solide autour d'un point fixe chez Hamilton". *Revue d'histoire des mathématiques* 1 (1995), 83-109.

This article reveals that Hamilton's 1848 paper "On quaternions and the rotation of a solid body" evinces several algebraic concepts (endomorphism, conjugation, characteristic polynomial) that played a major role in the last phase of Hamilton's work. In particular, the author argues that the case of duality shows how his mathematics was linked to his readings and optical-physical investigations from the 1830s.

2531. Straume, Eldar. "Lie's continuous and infinitesimal groups". *Normat* 40 (1992), 160-171.

An elementary and expository account of how Lie developed his theory of continuous groups, and of his work on differential equations (which were central to most of his work, although his methods are highly geometrical).

2532. Van der Waerden, Bartel Leendert. "Die Algebra seit Galois". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 68 (1966), 155–165.

Discussion of the three sources of modern or abstract algebra: ideal theory, group theory, field theory founded by Galois (1830) and Dedekind (1871). The analysis ends in 1934.

2533. Van der Waerden, Bartel Leendert. "Die Galois-Theorie von Heinrich Weber bis Emil Artin". *Archive for History of Exact Sciences* 9 (1972/1973), 240–248.

This paper discusses the work of Hilbert and his school, which is omitted by Kiernan, item 2507.

2534. Van der Waerden, Bartel Leendert. "On the Sources of My Book *Moderne Algebra*". *Historia Mathematica* 2 (1975), 31–40.

A detailed reminiscence about those mathematicians (especially E. Noether) who influenced the material in the most influential textbook in abstract algebra. See also his articles on Galois theory and algebraic geometry in *Archive for History of Exact Sciences* 7 (1971), 171–180; 9 (1972), 240–256.

2535. Van der Waerden, Bartel Leendert. *A History of Algebra from al-Khwarizmi to Emmy Noether*. Berlin: Springer-Verlag, 1985.

Dividing his work into three parts, van der Waerden treats the development of algebraic equations from al-Khwarizmi to C. Jordan, group theory to Weyl, and algebras from Hamilton to von Neumann. This is a highly personal selection and is therefore far from comprehensive. Yet, while van der Waerden's historiographical style may be unsatisfactory, this remains the only work of its kind, and is still a useful starting point for further references.

2536. Waterhouse, W. C. "The Early Proofs of Sylow's Theorem". *Archive for History of Exact Sciences* 21 (1980), 279–290.

Surveys Sylow's and Frobenius's proofs and their origins in Cauchy's work in order to highlight the difference between permutation-theoretic and abstract proofs as they arose in nineteenth-century group theory.

2537. Wussing, Hans. "Über den Einfluss der Zahlentheorie auf die Herausbildung der abstrakten Gruppentheorie". In *Beiheft zur NTM-Schriftenreihe für die Geschichte der Naturwissenschaften, Technik und Medizin.* Leipzig, 1964, 71–88.

The article investigates the influence of number theory on the creation of abstract group theory.

2538. Wussing, Hans. *The Genesis of the Abstract Group Concept: A Contribution to The History of the Origin of Abstract Group Theory.* Cambridge, MA: MIT Press, 1984. English translation by

Abe Shenitzer with the editorial assistance of Hardy Grant of *Die Genesis des abstrakten Gruppenbegriffes*. Berlin: VEB Deutscher Verlag der Wissenschaften, 1969, 258 pp.

The book is an exhaustive study of the development of the group concept, particularly thorough in its survey of implicit group-theoretical ideas in geometry and number theory. Permutation groups and Galois theory are considered in detail, with particular emphasis on C. Jordan's work, as is the emergence of transformation groups in Klein's Erlanger Programm and Lie's work. A final section considers the axiomatization of abstract group theory. Very extensive bibliography of primary and secondary literature (747 items).

2539. Zassenhaus, H. "Methoden und Probleme der modernen Algebra" *Jahresbericht der Deutschen Mathematiker-Vereinigung* 96 no. 1 (1994), 21–33.

This paper gives the views of the famous algebraist as reflected in his inaugural speech at the University of Hamburg in 1947. It forms an appendix to his obituary.

Linear Algebra, Algebraic Geometry, Invariant Theory, and Logic (With Regard to Algebra)

2540. Bos, H. J. M. "Arguments on Motivation in the Rise and Decline of a Mathematical Theory; the 'Construction of Equations', 1637-ca.1750". *Archive for History of Exact Sciences* 30 (1984), 331-380.

A discussion of the geometrical construction of polynomials in one unknown, a recognized and standard topic of algebra for about a century after Descartes's *Géométrie*. This article also speculates on the underlying motivations which resulted in its abandonment after the mid-18th century. Excellent bibliography.

2541. Crilly, Tony. "the Rise of Cayley's Invariant Theory (1841-1862)". *Historia Mathematica* 13 (1986), 241-254.

A discussion of Arthur Cayley's early work on invariants in the light of previously unpublished correspondence with fellow invariant theorists George Boole and James Joseph Sylvester.

2542. Crilly, Tony. "The Decline of Cayley's Invariant Theory (1863-1895)". *Historia Mathematica* 15 (1988), 332-347.

This analysis of Cayley's later work on invariant theory contrasts the computational approach, epitomised by the work of Cayley and Sylvester, with the increasingly powerful German symbolic method, championed by Paul Gordan. It highlights both the character of this empirical approach and its inherent weakness.

2543. Dieudonné, Jean. "The Historical Development of Algebraic Geometry". *American Mathematical Monthly* 79 (1972), 827–866.

A summary of the main themes in the history of algebraic geometry (particularly the notions of classification and transformation), described in terms of seven periods. The bulk of the article treats the fifth period ("Development and Chaos: 1866–1920"), which gave rise to the Riemann-Roch Theorem and to the Brill-Noether theory of linear systems; the sixth period ("New Structures: 1920–1950"), which saw generalized Stokes's theorems and abstract algebraic geometry; and the seventh period ("Sheaves and Schemes: 1950–"), which extended the Riemann-Roch Theorem to higher-dimensional varieties and utilized vector bundles.

2544. Dorier, Jean-Luc. "A General Outline of the Genesis of Vector Space Theory". *Historia Mathematica* 22 (1995), 227-261.

This paper presents a survey of the origin and development of fundamental concepts in the theory of vector spaces. It analyses the factors which brought about the initial formulation of a unification of linear questions around the concept of the determinant and discusses how this framework was generalized.

2545. Grattan-Guinness, Ivor. "Benjamin Peirce's *Linear Associative Algebra* (1870): New Light on its Preparation and 'Publication' ". *Annals of Science* 54 (1997), 597-606.

A re-examination of the background to the initial appearance of Peirce's ground-breaking classification of algebras, whose original publication was by lithography in an edition of 100, because the National Academy of Sciences could not afford to publish it.

2546. Günther, Siegmund. *Lehrbuch der Determinanten-Theorie für Studirende.* 2nd ed. Erlangen, 1877, 1–31.

The first 31 pages give an outline of the development of determinant theory from Leibniz to Hesse. The author especially pays attention to the development of an index notation.

2547. Hayashi, Tsuruichi. "The 'Fukudai' and Determinants in Japanese Mathematics". *Tokyo Sugaku-Buturigakkwai Kizi* (Proceedings of the Tokyo Mathematico-Physical Society), Series 2, 5 (1910), 254–271. Italian version: *Giornale di matematiche di Battaglini*, Serie 3, 50 (1912), 193–211.

The paper investigates the *Fukudai* problems and the determinant theory required in the solution of these problems, and analyzes the content of Seki Kowa's Fukudai-wo-kaisuru-ho, and the method of expanding a determinant in Japanese mathematics as well.

2548. Knobloch, Eberhard. "Zur Vorgeschichte der Determinantentheorie". *Akten des III. Internationalen Leibniz Kongresses, Hannover 12.-17.*

November 1977. Bd. 4. *Naturwissenschaften, Technik, Medizin, Mathematik.* (Studia Leibnitiana Supplementa XXII). Wiesbaden, 1982, 96–118.

The paper analyzes the development of Leibniz's index notation with regard to determinant theory, its propagation and influence.

2549. Knobloch, Eberhard. "Die entscheidende Abhandlung von Leibniz zur Theorie linearer Gleichungssysteme". *Studia Leibnitiana* 4 (1972), 163–180.

The paper analyzes and edits Leibniz's most important manuscript worked out in 1684, which is concerned with the solution of systems of linear equations.

2550. Knobloch, Eberhard. "Determinants". In Ivor Grattan-Guinness, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* New York: Routledge, 1994, 766-774.

A broad general survey of the history of determinants, touching on Far Eastern origins, the work of Leibniz, the first 18th-century publications on the rudiments of the subject, and the ground-breaking 19th-century contributions of Gauss,Cauchy, C. G. Jacobi, Cayley, Weierstrass and Kronecker.

2551. Laita, Luis Maria. "A Study of the Genesis of Boolean Logic". Dissertation, University of Notre Dame, 1976, 261 pp.

The origins of Boole's discovery of algebraic logic are discussed. The final chapter gives a list of the influences which Laita sees as leading to the construction of Boole's logic. Useful bibliography.

2552. Mellberg, Edvard Julius. *Teorin för Determinant-kalkylen.* Helsinki: J. C. Frenckell & Son, 1876.

The first part (pages 1–50) entitled "Historisk" gives an outline of the development of determinant theory from Leibniz up to 1870, after the first textbooks on this theory had been published.

2553. Meyer, Franz M. "Bericht über den gegenwartigen Stand der Invariantentheorie". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 1 (1890–1891), 79–288.

A valuable report on the state of the art (c. 1890) and thorough on recent, mostly German, developments, but makes almost no attempt to look at the British origins (Cayley and G. Boole).

2554. Mikami, Yoshio. "On the Japanese Theory of Determinants". *Isis* 2 (1914–1919), 9–36.

The paper is concerned with the Japanese contributions to determinant theory which are independent of the progress made in the West (17th and early 18th centuries).

2555. Moore, Gregory H. "The Axiomatization of Linear Algebra: 1875-1940". *Historia Mathematica* 22 (1995), 262-303.

A detailed answer to the question "How did the fundamental notions of vector space and module come to be isolated and then axiomatized?" taking in the work of (amongst many others) Peano, Weyl, Wiener, Banach, Hilbert and Noether. Excellent bibliography.

2556. Muir, Thomas. *The Theory of Determinants in the Historical Order of Development.* London: Macmillan, 1890. 2nd ed. of Vol. 1, 1906; Vols. 2–4, 1906–1923. Reprinted New York: Dover, 1960, 4 vols. in 2.

No current history, but short summaries of all papers from 1693 to 1899 (Studnička) concerned with determinant theory in their chronological order of publication. Useful chronological lists of writings.

2557. Muir, Thomas. *Contributions to the History of Determinants 1900–1920.* London, Glasgow: Blackie and Son, 1930.

Short summaries of writings published between 1900 and 1920 (with lists of authors whose writings are reported on) and subject index.

2558. Parshall, Karen Hunger. "Toward a History of Nineteenth-century Invariant Theory". In David E. Rowe, and John McCleary, eds. *The History of Modern Mathematics.* Vol. 1. San Diego: Academic Press, 1989, 157-206.

An examination of British (chiefly Cayley and Sylvester) and German (Aronhold, Clebsch and Gordan) work on invariant theory during the nineteenth century. It draws on the the Cayley-Sylvester correspondence regarding Gordan's finiteness theorem of 1868 to highlight the profound differences between the two approaches.

2559. Parshall, Karen Hunger. "The One-hundredth Anniversary of the Death of Invariant Theory?" *The Mathematical Intelligencer* 12 (4) (1990), 10-16.

This paper questions whether Hilbert's famous paper of 1890 ("Über die Theorie der algebraischen Formen") really did mark the death of invariant theory as mathematical legend would have us believe. It argues that continued work in the area well into the 1920s and the resurgence of invariant theoretic work from the 1960s suggest that it underwent a dormant period rather than extinction.

2560. Studnička, Franz Joseph. "A. L. Cauchy als formaler Begründer der Determinantentheorie; eine literarisch-historische Studie". *Abhandlungen der königlichen bömischen Gesellschaft der Wissenschaften von Jahre 1875 und 1876, Abhandlungen der* *mathematisch-naturwissenschaftlichen Classe* (Prague) VIII (1877). Also printed separately, Prague: n. p., 1876, 39 pp.

The paper tries to prove that Cauchy was the formal founder of determinant theory and discusses Cauchy's relevant papers as well as those of his predecessors.

Special National Developments (Other Than Britain)

2561. Bell, Eric Temple. "Fifty Years of Algebra in America, 1888–1938". *American Mathematical Society Semicentennial Publications.* Vol. 2: *Semicentennial Addresses of the American Mathematical Society.* New York, 1938, 1–34. 2 vols.

The influences that appear to have been mainly responsible for the evolution of abstract algebra in America are kept in view. Bell discusses the main contributions of the most important American algebraists of the period considered (especially Miller, Dickson).

2562. Bottazzini, Umberto. "Algebraische Untersuchungen in Italien, 1850–1863". *Historia Mathematica* 7 (1980), 24–37.

Brioschi's work in invariant theory and Betti's on Galois theory are briefly described and shown to have been influenced by Cayley and Sylvester before 1858, when they made their celebrated journey with Casorati. After that time Betti turned to analysis, under Riemann's influence.

2563. Hormigón, Mariano. "García de Galdeano's Works on Algebra". *Historia Mathematica* 18 (1991), 1-15.

This study of the algebra texts of Galdeano (1846-1924), from *Tratado de Algebra* (1883) onwards, shows that they marked not only an advance in the assimilation of nineteenth-century mathematics into Spain, but also proposed a new synthetic and didactic approach to this discipline.

2564. Mal′cev, Anatolii I. "On the History of Algebra in the USSR during the First Twenty-Five Years". *Algebra and Logic* 10 (1971), 68–75.

Survey of the Russian contributions to algebra from 1900 up to the time after the Second World War. It proves that in early years algebraic researches in Russia had been slower than in a number of other branches of mathematics.

2565. Pycior, Helena M. "British Synthetic vs. French Analytic Styles of Algebra in the Early American Republic". In David E. Rowe, and John McCleary, eds., *The History of Modern Mathematics.* Vol. 1. San Diego: Academic Press, 1989, 125-155.

This paper re-examines the previously-held view that, following the American Revolution, British mathematical textbooks were replaced by French works. Using four American algebra textbooks from the early nineteenth century, the author shows that American educators did not universally adopt the French analytic style in place of the British synthetic approach. Instead, it is argued that the new nation supported mathematical heterogeneity.

British Algebra

2566. Bloor, David. "Hamilton and Peacock on the Essence of Algebra". In Herbert Mehrtens, H. J. M. Bos, and Ivo Schneider, eds. *Social History of Nineteenth Century Mathematics*. Boston, Basel, Stuttgart: Birkhäuser, 1981.

Although the author remarks that it is "far ... from being an acceptable piece of historical scholarship," this paper is nevertheless a very interesting attempt to present a sociological and political explanation of conceptual differences between George Peacock and the English school of symbolic algebraists, and William Rowan Hamilton.

2567. Durand-Richard, Marie-José. "L'école algébrique anglaise et les conditions conceptuelles et institutionnelles d'un calcul symbolique comme fondement de la connaissance". In Catherine Goldstein, Jeremy Gray, and Jim Ritter, eds. *L'Europe mathématique - Mathematical Europe*. Paris: Éditions de la Maison des sciences de l'homme, 1996, 447-477.

This paper studies the British algebraic school of the early nineteenth century, which originated with the introduction of continental mathematics into Cambridge by the likes of Peacock, Babbage and Herschel. It offers philosophical and institutional explanations as to why such a symbolic movement began in England rather than France, where its underlying ideas were already well known.

2568. Fisch, Menachem. "'The Emergency Which Has Arrived': the Problematic History of Nineteenth-century Algebra - a Programmatic Outline". *British Journal for the History of Science* 27 (1994), 247-276.

A discussion of the factors which contributed to the revitalization of British mathematics in the early nineteenth century. The external influences are well-known, but there were also internal deliberations: convoluted intellectual self-reflective quests of original minds of the first order who interacted in a complex and multifaceted debate that we are only gradually beginning to unravel.

2569. Koppelman, Elaine. "The Calculus of Operations and the Rise of Abstract Algebra". *Archive for History of Exact Sciences* 8 (1971/1972), 155–242.

The paper tries to explain why, following the introduction of the differential notation, the first important English contributions to mathematics were made in algebra rather than in analysis. Its thesis is that the work in algebra among the algebraic formalists like Peacock, as well as De Morgan, Hamilton, and G. Boole, was a direct response of the

English to a specific aspect of the work of continental analysis. This subject came to be called, by the English, the calculus of operations. See also item 2726.

2570. Nagel, Ernest. "'Impossible Numbers': A Chapter in the History of Modern Logic". *Studies in the History of Ideas* 3 (1935), 429–474. Reprinted in Ernest Nagel, *Teleology Revisited and Other Essays in the Philosophy and History of Science*. (The John Dewey Essays in Philosophy, edited by the Department of Philosophy, Columbia University, no. 3.) New York: Columbia University Press, 1979.

An important essay which interweaves philosophical and historical insights. Presents G. Boole's mathematical formulation of logic as an extension of the algebraic work of De Morgan, D. F. Gregory, W. R. Hamilton, and Peacock. Suggests a connection between the problem of the negative and complex numbers and abandonment of the definition of mathematics as the science of quantity. Also relates the ideas of Playfair, Wallis, Warren, and Woodhouse to the development of symbolical algebra. Especially useful for footnote references and provocative original quotations. See also item 4138.

2571. Olson, Richard. "Scottish Philosophy and Mathematics 1750–1830". *Journal of the History of Ideas* 32 (1971), 29–44.

Argues that "the epistemological doctrines associated with the Common Sense philosophy of Thomas Reid and Dugald Stewart not only reinforced an appreciation of geometrical reasoning, but also provided a significant obstacle to the acceptance of analytical methods by Scottish mathematicians." Discusses Reid's ideas on the geometry of visibles.

2572. Olson, Richard. *Scottish Philosophy and British Physics, 1750–1880: A Study in the Foundations of the Victorian Scientific Style*. Princeton: Princeton University Press, 1975, 349 pp.

Argues that Scottish Common Sense philosophy exerted a major influence on late 18th- and 19th-century British physics. Cites the physicists' predilection towards geometrical mathematics, drive for simplicity, and concern with hypotheses and analogies as evidence for the thesis. Part 1 deals with the ideas of Reid, Stewart, Brown, and W. Hamilton; part 2, with Common Sense elements in the physics of Robison, Playfair, Leslie, Brougham, Forbes, Waterston, J. F. W. Herschel, Rankine, and Maxwell. Especially interesting is Chapter 3: "Common Sense Concerns with the Nature of Mathematics" which explores the extent of the Common Sense philosophers' acceptance of mathematics as a paradigm for philosophy and the physical sciences. This chapter covers W. Hamilton's attack on the mathematics as an integral part of a liberal education and mentions Reid's geometry of visibles. The book contains many lengthy quotations, some with but brief commentary. A review by Cantor, G. N. has attacked its major premise, claiming that it is "impossible to speak, in any unified sense, of Common Sense philosophy or of its influence" (*British Journal for the History of Science* 10 [1977], 81–83).

2573. Panteki, Maria. "William Wallace and the Introduction of Continental Calculus to Britain: a Letter to George Peacock". *Historia Mathematica* 14 (1987), 119-132.

An interesting analysis of a letter written by a little-known Scottish mathematician, William Wallace to George Peacock in 1833, which reveals many interesting facts concerning his role in the reform of British mathematics in the early nineteenth century. It contains a brief account of Wallace's life and work, as well as the full text of the letter.

2574. Pycior, Helena M. "George Peacock and the British Origins of Symbolical Algebra". *Historia Mathematica* 8 (1981), 23-45.

A survey of Peacock's work on symbolical algebra in the context of the early nineteenth-century British algebraic concerns over negative numbers. It argues that, although he recognized the possibility of defining arbitrary algebraic laws, he never actually did so. Contains a nice final section on William Rowan Hamilton's criticism of Peacock's approach.

2575. Pycior, Helena M. "Early Criticism of the Symbolical Approach to Algebra". *Historia Mathematica* 9 (1982), 392-412.

Complementing Pycior, item 2574, this paper makes good use of published and unpublished sources to show that Hamilton was far from alone in his criticism of Peacock's symbolic algebra. In addition to the strong criticisms of mathematical conservatives William Frend and Osborne Reynolds attention is also drawn to the reservations of more progressive scholars such as Augustus De Morgan, William Whewell, and Philip Kelland.

2576. Pycior, Helena M. "Augustus De Morgan's Algebraic Work: the Three Stages". *Isis* 74 (1983), 211-226.

A detailed analysis of De Morgan's changing views on algebra from 1828 to 1849, dividing this period into three stages: empiricist, abstract, and ambivalent. The author also suggests that this study offers insights into why the abstract algebraic trend prevalent in early-19th-century Britain had largely disappeared by the middle of the century.

2577. Pycior, Helena M. "Internalism, Externalism, and Beyond: 19th-century British Algebra". *Historia Mathematica* 11 (1984), 424-441.

Surveying the late 18th and early 19th-century debate in Britain over the legitimacy of crucial mathematical concepts in sound reasoning, this paper links the symbolical algebra of Babbage and Peacock to the nominalism of George Berkeley and Dugald Stewart.

2578. Pycior, Helena M. *Symbols, Impossible Numbers, and Geometric Entanglements. British Algebra through the Commentaries on Newton's "Universal arithmetick".* Cambridge: Cambridge University Press, 1997. xii + 328 pp.

The history of the development of British algebra in the seventeenth and early eighteenth centuries, focusing on the constitution of algebraic language.

2579. Richards, Joan L. "The Art and the Science of British Algebra: A Study in the Perception of Mathematical Truth". *Historia Mathematica* 7 (1980), 343–365.

Argues that what distinguished British algebra from modern algebra, and accounts for the different development of British algebra, is a fundamental difference between nineteenth- and twentieth-century views of truth.

2580. Richards, Joan L. "Augustus De Morgan the History of Mathematics, and the Foundations of Algebra". *Isis* 78 (1987), 7-30.

An analysis of De Morgan's views on the nature of mathematics in the wider context of his varied intellectual interests. In particular, it argues that De Morgan's historical attitudes molded the way he approached his mathematical research.

2581. Richards, Joan L. "Rigor and Clarity: Foundations of Mathematics in France and England 1800-1840". *Science in Context* 4 (1991), 297-319.

A comparative study of 19th-century mathematics in France and England, which developed along stylistically different lines, most easily seen on the foundational level. The author contends that the different cultural matrices which supported mathematics in France and Britain in the first decades of the nineteenth century shed light on the real though often subtle differences in the ways the subject was pursued.

ANALYSIS

2582. Alexander, Daniel S. *A History of Complex Dynamics*. Braunschweig: Vieweg, 1994.

The book is motivated by the question what led Fatou and Julia to study the iteration of a rational complex-analytic function in the first two decades of the 20th century.

2583. Andersen, Kirsti. "Cavalieri's Method of Indivisibles". *Archive for History of Exact Sciences* 31 (1985), 291-367.

Discusses Cavalieri's pre-calculus method as revealed in his papers of 1635 and 1647.

2584. Archibald, Thomas. "Riemann and the Theory of Electrical Phenomena: Nobili's Rings". *Centaurus* 34 No. 3 (1991), 247-271.

Discusses influence of Riemann's work *Zur Theorie der Nobilischen Farbenringe*.

2585. Archibald, Thomas. "From Attraction Theory to Existence Proofs: The Evolution of Potential-theoretic Methods in the Study of Boundary-value Problems, 1850-1890". *Rev. Hist. Math.* 2 No.1 (1996), 67-93.

Among the topics discussed: Carl Neumann's "physical method" and H. A. Schwarz's alternating method and their influence on É. Picard's method of successive approximation. See also item 2705 for another article by Archibald.

2586. Ayoub, R. "Euler and the Zeta Function". *American Mathematical Monthly* 81 (1974), 1067–1086.

Beginning with a short biography of Euler, goes on to consider Euler's attempts to evaluate what is today called the Riemann zeta function. Although unsuccessful, Euler did discover its functional equation for integral values of the independent variable.

2587. Bachmakova, Isabella G. "Les méthodes différentielles d'Archimède". *Archive for History of Exact Sciences* 2 (1964), 87–107.

The author argues that Archimedes's method of finding tangents, as in his "On Spirals," influenced geometers of the 17th century (e.g., Torricelli) in laying the basis for differential calculus.

2588. Barrow-Green, June. *Poincaré and the Three Body Problem.* Vol. 11 (History of Mathematics.) Providence, R.I. and London: American Mathematical Society and London Mathematical Society, 1997.

Discusses Poincaré's paper on the three-body problem, published in *Acta Mathematica* in 1890, which is the first mathematical description of chaotic behaviour in a dynamical system.

2589. Behnke, Heinrich, and Klaus Kopfermann, eds. *Festschrift zur Gedächtnisfeier für Karl Weierstrass 1815-1897.* Köln etc.: Opladen, 1966.

Almost half (240 pp.) of the book consists of articles on Weierstrass's biography and his work, written mostly by mathematicians. Since a biography is lacking, the book is still useful as a first source for information on the complete Weierstrass.

2590. Bernkopf, Michael. "The Development of Function Spaces with Particular Reference to their Origins in Integral Equation Theory". *Archive for History of Exact Sciences* 3 (1966/67), 1–96.

A detailed treatment of some early work in functional analysis. Emphasizes D. Hilbert's researches on integral equations, M. Fréchet's theory of abstract spaces, the researches on Hilbert spaces by E. Schmidt and F. Riesz, and S. Banach's creation of Banach spaces.

2591. Bernkopf, Michael. "A History of Infinite Matrices. A Study of Denumerably Infinite Linear Systems as the First Step in the History of Operations Defined on a Function Space". *Archive for History of Exact Sciences* 4 (1967/1968), 308–358.

Emphasizes the origins of infinite matrices in the work of H. Poincaré and its continuation by H. von Koch. Culminates in J. von Neumann's study of Hermitian operators on Hilbert space. It is established that, as was the case in finite dimensions, the theory of infinite dimensional operators preceded the theory of the appropriate infinite dimensional spaces.

2592. Birkhoff, Garrett. *A Source Book in Classical Analysis.* Cambridge, Mass.: Harvard University Press, 1973.

See items 101 and 2282.

2593. Birkhoff, Garrett, and Erwin Kreyszig. "The Establishment of Functional Analysis". *Historia Mathematica* 11 (1984), 258-321.

The article surveys the evolution of functional analysis, from its origins in the calculus of variations, the operational calculus, and the theory of integral equations until its establishment as an independent discipline around 1933.

2594. Bochner, S. "The Rise of Functions". In *Complex Analysis.* (Rice University Studies 56.) Houston, Tex.: William Marsh Rice University, 1970, 3–21.

Beginning with antiquity, the author surveys the subsequent development of concepts, including continuity, piecewise analytic functions, trigonometric series, orthogonal systems, and analytic continuation. A short but good general introduction.

2595. Bochner, S. "Singularities and Discontinuities". *Complex Analysis. Vol. II.* (Rice University Studies, 59.) Houston, Tex.: William Marsh Rice University, 1973, 21–41.

An eclectic study of important work on singularities in the 19th and 20th centuries with links to 18th-century mathematics and a glance back to ancient Greece. Bochner sees an anomaly in that Greek mathematics lacked a theory of continuity, while Greek philosophy *had* such a concept. Discusses Cauchy's residue formula plus Hartog's discovery of the importance of nonsingularities for the theory of complex variables.

2596. Bohlman, G. "Uebersicht ueber die wichtigsten Lehrbücher der Infinitesimal-Rechnung von Euler bis auf die heutige Zeit". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 6 II (1899), 91–110.

Dated, but still very useful for anyone interested in pedagogical traditions. The works are divided on a thematic rather than a strictly chronological basis. The arithmetization of analysis is followed from Euler through Lagrange, Cauchy, and finally Weierstrass. Other aspects include the naive approach, the systematic-arithmetic approach leading to Peano's work, and the philosophical and physical traditions.

2597. Borel, E. *Notice sur les travaux scientifiques de M. Emile Borel.* 2nd ed. Paris: Gauthier-Villars, 1921.

First issued in 1912, with supplements in 1918 and 1921. Written by Borel, this detailed self-evaluation of his work (71 pages) begins with a general introduction, followed by five chapters: I. Functions of a real variable; II. Functions of a complex variable; III. Entire functions and meromorphic functions; IV. Arithmetic, algebra, differential equations; V. Geometry, probability, and statistical mechanics. Bibliographies also included. The original *Notice* and supplements are reprinted in E. Borel, *Oeuvres de Emile Borel* (Paris: 'Editions du Centre National de la Recherche Scientifiques, 1972, in 4 vols.), Vol. 1, 119–201.

2598. Bos, H. J. M. "Differentials, Higher-Order Differentials and the Derivative in the Leibnizian Calculus". *Archive for History of Exact Sciences* 14 (1974), 1-90.

Valuable discussion of the concept of "differential" as employed in early Leibnizian calculus. Focuses on the techniques underlying the daily use of the differential rather than its logical foundations; elaborates the crucial role of variables as opposed to functions in the conceptual framework of the differential calculus. Argues that in Euler's attempts to eliminate the indeterminacy of higher order differentials the derivative emerged as the fundamental concept of the calculus.

2599. Bos, H.J.M. "Tractional Motion and the Legitimation of Transcendental Curves". *Centaurus* 31 No.1 (1988), 9-62.

Contains interesting observations on a phase of mathematics around 1700 (Huygens, Leibniz, Jakob Bernoulli and Johann Bernoulli) when geometrical concepts were slowly yielding ground to those of analysis and functions.

2600. Bottazzini, Umberto. "Le funzioni a periodi multipli nella corrispondenza tra Hermite e Casorati". *Archive for History of Exact Sciences* 18 (1977/78), 39–88.

2601. Bottazzini, Umberto. *The Higher Calculus: A History of Real and Complex Analysis from Euler to Weierstrass.* New York etc.: Springer, 1986.

A history of the introduction of rigour into analysis, especially in the work of Cauchy and Weierstrass. A translation from the Italian original (1981).

2602. Bottazzini, Umberto, ed. *Studies in the History of Modern Mathematics.* In two parts as Rendiconti Circ. Mat. Palermo (2) Suppl. 34 (1994), and Suppl. 44 (1996).

Vol. 34 contains contributions on the history of analysis by A. Dahan (on S. Lefschetz), J. Mawhin (Poincaré, Lyapunov), R. Tazzioli (Riemann). Vol. 44 contains contributions by Bottazzini (complex function theory) and P. Ullrich (Riemann mapping problem). See also item 2705 for another article by Bottazzini.

2603. Bourbaki, Nicolas. *Eléments d'histoire des mathématiques.* Paris: Hermann, 1966.

See items 886, 2298, 2337.

2604. Boyer, Carl B. *History of the Calculus and Its Conceptual Development.* New York: Dover, 1959.

This is an unaltered reprint of *The Concepts of the Calculus, a Critical and Historical Discussion of the Derivative and the Integral.* New York: Columbia University Press, 1939. Views the development of the calculus as an effort lasting 2500 years to explain a vague intuitive feeling for continuity. Argues that a hindrance to this development was the fact that concepts were not defined as concisely and formally as possible, and that the final answer was provided by the rigorous definitions of function and limit in the 19th century. See items 2078, 4056.

2605. Branges, Louis de, I. Gohberg, and James Rovnyak, eds. *Topics in Operator Theory. Ernst Hellinger Memorial Volume.* (Operator

Theory: Advances and Applications, 48.) Basel etc.: Birkhäuser, 1990.

Includes a paper by Rovnyak (pp.1-41) on Hellinger's life and work.

2606. Brill, A., and M. Noether. "Die Entwicklung der Theorie der algebraischen Funktionen in älterer und neuer Zeit". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 3 (1894), 107–566.

The only history of this immense topic, it covers early ideas (Descartes to Bézout), the French school (Lagrange, Cauchy, and Puiseux), Gauss, the theory of elliptic functions (Abel to Weierstrass), Riemann and his school, other schools of algebraic geometry (Clebsch and Gordan, Brill and Noether), the theory of singular points, and various special topics.

2607. Burkhardt, Heinrich. "Trigonometrische Reihen und Integrale bis etwa 1850". *Encyklopädie der mathematischen Wissenschaften, II (A12).* Leipzig: B. G. Teubner, 1914–1915, 819–1354.

A vast study with very thorough references. Discusses development of analytic functions via trigonometric series; also nonharmonic representations, Fourier integrals, integration of partial differential equations in two or more variables, and numerous applications.

2608. Burkhardt, Heinrich. "Entwicklungen nach oscillierenden Functionen und Integration der Differentialgleichungen der mathematischen Physik". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 10 (1901–1908), viii + 1804 pp. This was also issued separately in 2 vols., Leipzig: B. G. Teubner, 1908, xii + xii + 1800 pp. Reprinted New York: Johnson Reprint Corp., 1960.

See items 2888, 3221.

2609. Burkhardt, Heinrich. "Ueber den Gebrauch divergenter Reihen in der Zeit 1750–1860". *Mathematische Annalen* 70 (1911), 189–206.

An attempt to understand how 18th- and early 19th-century mathematicians dealt with infinite series before the advent of rigorous convergence tests and the modern theory of limits. The author suggests that this branch of analysis has diverse roots, but was largely unrelated to the one field in which rigor had been well established, namely, geometry.

2610. Butzer, Paul L.. "Dirichlet and His Role in the Founding of Mathematical Physics". *Arch. Int. Hist. Sci.* 37 No.118 (1987), 49-82.

Traces the different relationships of Dirichlet to his direct and indirect students and the influence coming therefrom on mathematics and physics.

2611. Butzer, Paul L., and R. J. Nessel. "Aspects of de La Vallée Poussin's Work in Approximation and Its Influence". *Archive for History of Exact Sciences* 46 No.1 (1993), 67-95.

An analysis of contributions to approximation theory made by de La Vallée-Poussin (1866-1962).

2612. Cajori, Florian. *A History of the Conceptions of Limits and Fluxions in Great Britain from Newton to Woodhouse.* Chicago and London: Open Court, 1919.

Argues that Berkeley's critique of the foundations of the fluxional calculus led to an early geometrical concept of limit (Robins). Thus the British treatment of the calculus in the 18th century gained clarity and logical rigor.

2613. Cajori, Florian. "The History of Notations of the Calculus". *Annals of Mathematics* 25 (1923), 1–46.

Considers development of notation from Newton and Leibniz to Peano and W. H. Young. Cajori contends that new notations have usually only been adopted when the need became imperative, while on the other hand a lack of suitable notation has often arrested progress in the subject.

2614. Calinger, Ronald. "Leonhard Euler: The First St.Petersburg Years (1727-1741)". *Historica Mathematica* 23 (1996), 121-166.

Article disputes Condorcet's thesis that Euler virtually ignored practice for theory. Uses Euler's correspondence, which was unpublished until the 1960s.

2615. Carathéodory, Constantin. "The Beginning of Research in the Calculus of Variations". *Osiris* 3 (1938), 224-240.

A still very useful and vivid first introduction in the early work in the calculus of variations, written by an eminent specialist in that field and based on primary historical sources.

2616. Cauchy, Augustin Louis. *Cours d'analyse de l'École Royale Polytechnique. Première partie: Analyse algébrique.* Vol. 7. Edited and introduced by U. Bottazzini. (Instrumenta Rationis. Sources for the History of Logic in the Modern Age.) Bologna: Editrice CLUEB, 1992.

Cauchy's book from 1821 is one of the milestones in the history of analysis, formulating many modern notions for the first time. The editor, U. Bottazzini, gives a detailed historical introduction.

2617. Charbonneau, Louis. *Catalogue des manuscripts de Joseph Fourier conservés au Cabinet des manuscripts de la Bibliothèque Nationale.* (Cahiers d'histoire et de philosophie des sciences, 42.) Paris: Blanchard, 1993.

2618. Chemla, Karine. "Méthodes infinitésimales en Chine et en Grèce ancienne: Les limites d'un parallele". In *Le labyrinthe du continu,* *Colloq., Cerisy-la-Salle (France), 1990.* (Paris: Springer-Verlag, 1992), 31-46.

A comparative study of proofs in the passages concerning the area of a circle and the volume of a pyramid in Euclid's *Elements* and in the Chinese classic "Nine Chapters".

2619. Cleave, J. P. "The Concept of 'Variable' in 19th-Century Analysis". *British Journal for the Philosophy of Science* 30 (1979), 266–278.

Cleave defends the position of Robinson and Lakatos, who argue that the foundations of Cauchy's calculus can best be understood as an anticipation of the approach of non-standard analysis.

2620. Cooke, Roger L. *The Mathematics of Sofya Kovalevskaya.* New York etc.: Springer, 1984.

Parallel to more biographical work on Kovalevskaya by A. H. Koblitz and others, this book presents the mathematical achievements of the Russian woman-mathematician who was, according to the author, "more gifted than most (mathematicians) but distracted from her work far more often as well."

2621. Cooke, Roger L. "Uniqueness of Trigonometric Series and Descriptive Set Theory". *Archive for History of Exact Sciences* 45 (1993), 281-334.

Begins with the precursors of Cantor and describes the developments of the theory up to the most recent contributions. Gives also an account of the Moscow school, and of its metaphysical point of view.

2622. Crowe, Michael J. *A History of Vector Analysis: The Evolution of the Idea of a Vectorial System.* New York: Dover, 1985. Reprint of 1967 edition with corrections and new bibliographical preface.

See item 2480.

2623. Dahan (-Dalmedico), Amy. "Un texte de philosophie mathématique de Gergonne". *Rev. Hist. Sci.* (1986), 39, 97-126.

Discusses a manuscript of 1813 by the geometer and analyst J. D. Gergonne on his philosophical understanding of analysis and synthesis in mathematics.

2624. Dahan (-Dalmedico), Amy. "Réalité physique et objets mathématiques chez Fourier". *Cah. Hist. Philos. Sci.* Nouv. Sér. 20 (1987), 241-255.

Discusses Fourier's notion of science and the relation to his work in the mathematical theory of heat conduction.

2625. Dahan (-Dalmedico), Amy. "La renaissance des systèmes dynamiques aux Etats-Unis après la deuxième guerre mondiale: L'action de Solomon Lefschetz". In *Studies in the History of Modern Mathematics*, Vol. I. Edited by U. Bottazzini. *Suppl. Rendiconti Circ. Mat. Palermo* (2) (1994), 34, 133-166. (Item 2602).

Is devoted to the revival of the study of dynamical systems, related to differential equations, in the United States after 1945. Includes a brief mathematical biography of Solomon Lefschetz (1884-1972).

2626. Dahan, Amy. "Le difficile héritage de Henri Poincaré en systèmes dynamiques". In: item 2681, 13-33.

Discusses the reception of Poincaré's work on dynamical systems in Russia and the U.S. by A. A. Andronov, P. S. Ljapunov, G. D. Birkhoff, M. Morse, and S. Lefschetz after 1912 until the 1970s.

2627. Dauben, Joseph Warren. *Georg Cantor, His Mathematics and Philosophy of the Infinite*. Cambridge, Mass.: Harvard University Press, 1979, 361 pp.. Paperback reprint, Princeton, N.J.: Princeton University Press, 1990.

Includes a detailed examination of how Cantor's early work on Fourier series led him to his revolutionary investigations of the real number line and ultimately the theory of sets. See items 3150, 4070.

2628. Davis, P. J. "Leonard Euler's Integral: A Historical Profile of the Gamma Function". *American Mathematical Monthly* 66 (1959), 849–869.

Describes Euler's early work, its generalization to the complex plane by Gauss, infinite factorizations by Weierstrass, the function-theoretic investigations of Hadamard, and the culminating characterization of the gamma function as given by the Bohr-Mollerup-Artin theorem.

2629. Deakin, Michael A. B. "The Development of the Laplace Transform, 1737–1937, I. Euler to Spitzer, 1737–1800". *Archive for History of Exact Sciences* 25 (1981), 343–390.

An attempt to provide a more balanced narrative history of the development of the Laplace transform, this study also clearly establishes Euler's priority in its discovery. See also item 3223.

2630. Deakin, Michael A. B. "The Development of the Laplace Transform, 1737-1937. II: Poincaré to Doetsch". *Archive for History of Exact Sciences* 26 (1982), 351-381.

Discusses integral transforms and operational calculus in S. Pincherle and others.

2631. Deakin, Michael A. B. "The Ascendancy of the Laplace Transform and How It Came About". *Archive for History of Exact Sciences* 44 (1992), 265-286.

As a sequel to previous articles this paper stresses textbooks (especially G. Doetsch) until World War II. Differences in mathematical rigour and presentation in different countries are mentioned.

2632. Demidov, Sergei S. "On the History of the Theory of Linear Differential Equations". *Archive for History of Exact Sciences* 28 (1983), 369-387.

On the history of analogies between linear algebraic and linear differential equations, especially on the work of Libri and Liouville.

2633. Demidov, Sergei S. "The Theory of Differential Equations At the Border of the 18th/19th Centuries". *Istoriko-matematicheskie Issledovanija* 34 (1993), 46-57. In Russian.

A sequel to a long list of publications in Russian on differential equations in the same journal.

2634. Dhombres, Jean, and Nicole Dhombres. *Lazare Carnot.* Paris: Fayard, 1997.

2635. Denjoy, A. "Arnaud Denjoy: évolution de l'homme et de l'oeuvre". *Astérisque.* Edited by G. Choquet. Paris: Société Mathématique de France, 1975, 28–29.

Henri Cartan provides the biographical appreciation. Denjoy's own "Mon oeuvre mathématique: sa genèse et sa philosophie" and "Le mécanisme des opérations mentales chez les mathématiciens" are also included, as is a bibliography of Denjoy's works.

2636. Dieudonné, Jean. *History of Functional Analysis.* Vol. 49. (North-Holland Mathematics Studies.) Amsterdam etc.: North Holland, 1983.

The very technical and comprehensive account is written by a prominent mathematician who considers the development of funtional analysis as a development of the study of topological vector spaces.

2637. Dobrovolskij, Wjatscheslav A. *Chapters of the History of the Analytic Theory of Differential Equations.* Kiew: Wischtscha Schkola, 1974. In Russian.

A mathematically very detailed and useful history of the analytic theory of differential equations which discusses both the general theory of nonlinear equations and the special problems in linear equations. The bibliography has almost 300 titles.

2638. Dorofeeva, Alla V. "The Calculus of Variations in the Last Third of the 19th Century". *Istor. Metodol. Estestv. Nauk, Mat., Mekh.* 29 (1982), 64-74. In Russian.

Centers on Weierstrass's proof of Euler's rule for isoperimetric problems.

2639. Dorofeeva, Alla V., and Vladimir M. Tikhomirov. "From the Rule of Lagrangian Multipliers to Pontryagin's Maximum Principle". *Istoriko-matematicheskie Issledovanija* 25 (1980), 104-128. In Russian.

On the history of necessary extremum conditions in problems with constraints in variational calculus from the 18th through the 20th centuries.

2640. Dugac, Pierre. "Eléments d'analyse de Karl Weierstrass. *Archive for History of Exact Sciences* 10 (1973), 41-176. "

Still valuable as a first introduction into Weierstrass's various lecture courses in Berlin on the foundations of analysis, especially on fundamental concepts such as the real numbers. Has various appendices with excerpts from the courses and correspondences concerning the foundations.

2641. Dugac, Pierre. *Histoire du théorème des accroissments finis.* Paris: Université Pierre et Marie Curie, 1979.

A study of concepts and related results leading to the proof of the Mean Value Theorem. Dugac argues that Dini was the first to give a rigorous proof; he also documents that Weierstrass was directly influenced by Bolzano by making use of the former's unpublished lecture notes and other materials. Related results include Rolle's Theorem, the Intermediate Value Theorem, Cauchy's criterion, and the Bolzano-Weierstrass Theorem.

2642. Dugac, Pierre. *Limite, point d'accumulation, compact.* Paris: Université Pierre et Marie Curie, 1980.

Of the three topics given in the title, limits receive the most attention. Dugac begins by a consideration of the zeros of an analytic function. The work of Bolzano and Cantor are featured, making ample use of unpublished materials.

2643. Dugac, Pierre. *Sur les fondements de l'analyse au XIXe siècle.* Louvain: Université Catholique de Louvain, 1980.

A history of the foundations of analysis from d'Alembert to Cantor and Dedekind. Includes bibliography and topics for examinations.

2644. Dugac, Pierre. "Notes et documents sur la vie et l'oeuvre de René Baire". *Archive for History of Exact Sciences* 15 (1976), 297–383.

See item 2366.

2645. Dumas, H. S., K. R. Meyer, and D. S. Schmidt, eds. *Hamiltonian Dynamical Systems: History, Theory, and Applications.* Vol. 63. (The IMA Volumes in Mathematics and Its Applications.) New York etc.: Springer, 1995.

2646. Edwards, C. H., Jr. *The Historical Development of the Calculus*. New York etc.: Springer, 1979, 2nd. edition 1982, , paperback 1994.

Still the most comprehensive and up to date history of analysis. Ten chapters cover material from Babylonian calculation to the Lebesgue integral. A lucid explanation of individual works by Archimedes, Wallis, Newton, Leibniz, Euler, and others, but short on historical analysis. Should be compared with *From the Calculus to Set Theory, 1630–1910*, edited by I. Grattan-Guinness, item 3141.

2647. Duren, W. L. "The Development of Sufficient Conditions in the Calculus of Variations". In *University of Chicago Contributions to the Calculus of Variations*. Vol. 1. Chicago: Chicago University Press, 1930, 245–349.

Gives background from Euler to C. G. Jacobi leading up to the first sufficiency proofs of Weierstrass and Scheefer. Discusses the stronger results obtained by Kneser, Hilbert, Osgood, Carathéodory, Bolza, and Tonelli, as well as work on the Lagrange and Mayer problems and various isoperimetric problems. Related works by Mayer, Kneser, Bliss, Hahn, and Morse handle the problem of obtaining sufficient conditions when endpoints are variable.

2648. Enneper, A. *Elliptische Funktionen: Theorie und Geschichte*. 2nd ed. Halle: L. Nebert, 1890.

A seven-page historical introduction followed by over 500 pages of text. Still this work will be useful for researchers who want *detailed* information about who did what in this important field of early 19th-century analysis. The treatment is topical and the author cites his references very thoroughly.

2649. Engelsman, S. B. *Families of Curves and the Origins of Partial Differentiation*. Dissertation, University of Utrecht, 1982. 234 pp. Rev. ed. (Mathematics Studies 93.) Amsterdam, New York, Oxford: North-Holland, 1984, ix + 238 pp.

Analyzes in detail how the concept of partial differentiation and the theorems on interchangeability of differentiation and integration and on the equality of mixed second order partial derivatives emerged in the work of Leibniz and the Bernoullis on trajectories in families of curves. Shows that Euler's work of the 1730s, related to partial differential equations, can be understood by considering it as part of the same tradition. Contains an edition of Euler's early manuscript "De differentiatione functionum duas pluresve variabiles quantitates involventium" (ca. 1730).

2650. Euler, Leonhard. *Zur Theorie komplexer Funktionen*. Vol. 261. Introduction and commentary by A. P. Youschkevitch. (Ostwalds

Klassiker der exakten Wissenschaften.) Leipzig: Akademische Verlagsgesellschaft, 1983.

Translations of several papers of Euler's on complex function theory from the Latin and French originals. With commentary by a specialist in Euler, A. P. Youschkevitch.

2651. Fauvel, John, Raymond Flood, Michael Shortland, Robin Wilson, eds. *Let Newton Be*! Oxford etc.: Oxford University Press, 1988.

Comprehensive volume on Newton and his work on the occasion of the tercentenary of Newton's *Principia*. Includes articles on Newton's work in analysis, but also on his reflections in theology etc.

2652. Feigenbaum, Lenore. *Brook Taylor and the Method of Increments*. *Archive for History of Exact Sciences*. 34 (1985), 1-140.

A penetrating study of Taylor's *Methodus incrementorum directa et inversa* (1715), taking into account unpublished correspondence of Montmort with Taylor and Bernoulli.

2653. Feingold, Mordechai. "Newton, Leibniz, and Barrow too. An Attempt at a Reinterpretation". *Isis* (1993), 84 No. 2 310-338.

The author claims in a interpretative essay that the argument for the independent codiscovery of the calculus by Newton and Leibniz does not hinge on the corollary dismissal of Barrow.

2654. Fisher, G. "The Infinite and Infinitesimal Quantities of du Bois-Reymond and Their Reception". *Archive for History of Exact Sciences* 24 (1981), 101–163.

Discusses reactions of Cantor, Dedekind, Peano, Russell, Pringsheim, Stolz, Borel, Hardy, Hausdorff, et al. Issues center around the validity and/or utility of theories of the infinitely large and small. Fisher cites this as a case study indicating the shortcomings of Lakatos's theory in *Proofs and Refutations*, ed. J. Worrall and E. G. Zahar (Cambridge, Eng.: Cambridge University Press, 1976).

2655. Flett, T. M. "Some Historical Notes and Speculations Concerning the Mean-Value Theorems of the Differential Calculus". *Bulletin of the Institute of Mathematics and Its Applications* 10 (1974), 66–72.

Explains why the attempts of Lagrange, Cauchy, and C. Jordan to prove the Mean-Value Theorem failed.

2656. Fraser, Craig G. "D'Alembert's Principle: The Original Formulation and Application in Jean d'Alembert's Traité de Dynamique (1743)". *Centaurus* 28 (1985), 31-61.

Follows in its interpretation work by C. Truesdell and I. Szabó and gives for the first time the mathematical details. Useful for the historical understanding of the analytical foundations of mechanics.

2657. Fraser, Craig G. "Joseph Louis Lagrange's Algebraic Vision of the Calculus". *Historica Mathematica* 14 (1987), 38-53.

Discusses Lagrange's algebraization of analysis, especially with respect to singularities in ordinary differential equations and to variational calculus.

2658. Fraser, Craig G. "The Origins of Euler's Variational Calculus". *Archive for History of Exact Sciences* 47 (1994), 103-141.

Discusses significant characteristics of the theories of Jakob Bernoulli, Johann Bernoulli, and Taylor as well as Euler's work on the variational calculus that preceded his seminal *Methodus inveniendi curvas lineas* (1744). Continues previous work by the author in the same journal (1985). See also item 2705 for another article by Fraser.

2659. Fréchet, M. "La vie et l'oeuvre d'Emile Borel". *L'Enseignement Mathématique* 11 (1965), 1–94.

A biography of 20 pages followed by a lengthy discussion of the general character of Borel's work. Consideration is given to his work in number theory, infinite series, set theory, measure theory, real variables, complex variables, differential equations, geometry, and applied mathematics.

2660. Fréchet, M. *Notice sur les travaux scientifiques de M. Maurice Fréchet.* Paris: Hermann, 1933.

Begins with a list of university degrees, teaching positions, and scientific awards and distinctions. Mathematical publications (pp. 7–25) are divided into seven categories: applied mathematics (7 publications); probability and errors (28 publications); geometry (29 publications); classical analysis (40 publications); and general themes (including pedagogy) (4 papers); pages 27–101 constitute Fréchet's own "Notice sur les travaux scientifiques."

2661. Freudenthal, H. "Did Cauchy Plagiarize Bolzano?" *Archive for History of Exact Sciences* 7 (1971), 375–392.

Freudenthal answers no, and in so doing, he attempts to refute Grattan-Guinness's argument in item 2677.

2662. Fritzsche, Bernd, and Bernd Kirstein, eds. *Ausgewählte Arbeiten zu den Ursprüngen der Schur-Analysis. Gewidmet dem großen Mathematiker Issai Schur (1875-1941).* Vol. 16. (Teubner-Archiv zur Mathematik.) Stuttgart and Leipzig: Teubner, 1991.

The reprinted articles by Schur, G. Herglotz, G. Pick, and R. Nevanlinna together with a epilogue by the editors, stress Issai Schur's peculiar "algorithmic" approach to analysis and its importance for today's research.

2663. Funk, P. "Bolzano als Mathematiker". *Sitzungsberichte Österreicher Akademie der Wissenschaften (Vienna)* 252, Teil 5 (1967), 121–134.

2664. Gandt, François de. "The Birth and Metamorphose of a Mathematical Theory: A Geometry of Indivisibles". *Cad. Hist. Filos. Cienc.* 10 (1986), 27-59. In Portuguese.

On the work of Galileo, Cavalieri, and Torricelli on the geometry of indivisibles between 1630 and 1650.

2665. Gandt, François de. *Force and Geometry in Newton's Principia*. Princeton: Princeton University Press, 1995.

Close reading of the text of Newton's *Principia* reveals the influence by Robert Hooke on Newton's idea of orbital motion.

2666. Geppert, H. "Bestimmung der Anziehung eines elliptischen Ringes, Nachlass zur Theorie der arithmetischen-geometrischen Mittels und der Modulfunktionen von C. F. Gauss". (Ostwald's Klassiker der exakten Wissenschaften, No. 225). Leipzig: Akademie Verlagsgesellschaft, 1927.

A thorough and fascinating reconstruction of Gauss's theory of elliptic functions reconstructed from the *Nachlass*.

2667. Gibson, G. A. "James Gregory's Mathematical Work". *Proceedings of the Edinburgh Mathematical Society* (1922/1923), 2–35.

Drawn primarily from Rigaud's *Correspondence of Scientific Men of the Seventheenth Century, vol. 2*, and the *Commercium Epistolicum*, compiled by John Collins. Attempts to determine Gregory's role in the early development of calculus.

2668. Gispert, Hélène. "Sur les fondements de l'analyse en France (à partir de lettres inédites de G. Darboux et de l'étude des différentes éditions du Cours d'analyse à l'École polytechnique de C. Jordan). *Archive for History of Exact Sciences* 28 (1983), 37-106. "

2669. Glimm, James, John Impagliazzo, and Isadore Singer, eds. *The Legacy of John von Neumann.* Vol. 50. (Proceedings of Symposia in Pure Mathematics.) Providence, R.I.: American Mathematical Society, 1990.

Contains articles by prominent mathematicians on von Neumann's work in ergodic theory, rings of operators, mathematical physics, computing, game- and automata theory, and philosophy.

2670. Gohberg, I., ed. *Toeplitz Centennial. Toeplitz Memorial Conference in Operator Theory, Dedicated to the 100th Anniversary of the Birth of*

Otto Toeplitz Tel Aviv 1981. (Operator Theory: Advances and Applications, vol. 4) Basel etc.: Birkhäuser, 1982.

2671. Goldstine, Herman H. *A History of Numerical Analysis from the 16th through the 19th Century.* New York, Heidelberg, Berlin: Springer, 1977.

See item 3516.

2672. Goldstine, Herman H. *A History of the Calculus of Variations from the 17th through the 19th Century.* New York, Heidelberg, Berlin: Springer, 1980.

2673. Golovinskij, Ilya A. "On Cauchy's Interpolation Method". *Istoriko-matematicheskie Issledovanija* 28 (1985), 26-78. In Russian.

Shows the generality of Cauchy's method against the background of the theory of the approximation of functions in the 19th century.

2674. Golovinskij, Ilya A. "On the Basis of the Method of Least Squares in P. L. Chebyshev". *Istoriko-matematicheskie Issledovanija* 30 (1986), 224-247. In Russian.

Describes Chebyshev's work (1854-1875), inspired by the problem of interpolating functions.

2675. Grabiner, J. V. *The Origins of Cauchy's Rigorous Calculus.* Cambridge, Mass.: MIT Press, 1981.

Offers an excellent introduction to the history of the calculus in the 17th century, with special attention given to detailed study of Lagrange and his importance for the later work of Cauchy. Cauchy's definition, a rigorous one in $\epsilon - \delta$ terms, is traced back via Ampère to Lagrange, and the significance of this for the form of Cauchy's foundations of analysis is discussed.

2676. Grattan-Guinness, Ivor. "Berkeley's Criticism of the Calculus as a Study in the Theory of Limits". *Janus* 56 (1969), 215–227.

The explication of Berkeley's criticism of the calculus is related to his theological views and philosophical Idealism. Mention is also made of the reaction of contemporaries to Berkeley's *The Analyst.*

2677. Grattan-Guinness, Ivor. "Bolzano, Cauchy and the 'New Analysis' of the Early Nineteenth Century". *Archive for History of Exact Sciences* 6 (1970), 372–400.

Argues that Cauchy plagiarized Bolzano based on the coincidence of ideas in the latter's 1817 pamphlet and in the *Cours d'analyse*, the social scene surrounding Parisian mathematics, and Cauchy's personality. This argument has been rebutted in item 2661.

2678. Grattan-Guinness, Ivor. *The Development of the Foundations of Mathematical Analysis from Euler to Riemann.* Cambridge, Mass.: MIT Press, 1970, 186 pp.

Discusses topics in the theory of limits and convergence from the early discussions of the problem of the vibrating string by Euler, d'Alembert, and Lagrange to the rigorous methods of the successors of Cauchy and Dirichlet. Some of its arguments, notably that Cauchy might have plagiarized Bolzano, and the distinction between limit avoidance and limit achievement, have not met with general acceptance, but the book is a vivid and stimulating account of an important subject. It also contains a thorough bibliography.

2679. Grattan-Guinness, Ivor. "Preliminary Notes on the Historical Significance of Quantification and of the Axioms of Choice in the Development of Mathematical Analysis". *Historia Mathematica* 2 (1975), 475–488.

A programmatic sketch of topics for future study and their significance for the history of mathematics.

2680. Grattan-Guinness, Ivor. *Convolutions in French Mathematics, 1800-1840.* Vol. I: *The Settings.* Vol. II: *The Turns.* Vol. III: *The Data.* (Science Networks. Historical Studies, 2–4.) Berlin and Basel: VEB Deutscher Verlag der Wissenschaften and Birkhäuser, 1990.

A useful source of reference for primary material of the period considered.

2681. Greffe, Jean-Louis, Gerhard Heinzmann, and Kuno Lorenz, eds. *Henri Poincaré.* Science et philosophie (Henri Poincaré: Science and Philosophy. International Congress Nancy, France, 1994). Berlin and Paris: Akademie Verlag and Albert Blanchard, 1996. In English, French, German.

More on Poincaré's work in geometry, physics, and logics than analysis. See, however, Amy Dahan Dalmedico, "Le difficile heritage de Henri Poincaré en systemes dynamiques" (item 2626).

2682. Grigorian, Aschot T., and Boris D. Kovalev *Daniel Bernoulli 1700-1782.* Moskva: Nauka, 1981. In Russian.

A biography of Daniel Bernoulli which stresses his work in mathematical physics and does not go very much into the technical details of the mathematics.

2683. Guicciardini, Niccolo. *The Development of Newtonian Calculus in Britain 1700-1810.* Cambridge: Cambridge University Press, 1989.

A comprehensive account. Shows the generally accepted views on the crisis of the Newtonian calculus to be untenable. See also item 2705 for another article by Guicciardini.

2684. Hadamard, J. *Notice sur les travaux scientifiques de M. Jacques Hadamard. Vol. 1.* Paris: Gauthier-Villars, 1901. Reprinted, with vol. 2, Paris: Hermann, 1912.

Volume 1 covers Hadamard's works from 1884 to 1901, with a bibliography on pp. 7–11; volume 2 includes publications from 1901 to 1912 and has a bibliography on pp. 7–13.

2685. Hall, A. R. *Philosophers at War: The Quarrel Between Newton and Leibniz.* Cambridge: Cambridge University Press, 1980.

See item 2169.

2686. Hankins, Thomas. *Jean d'Alembert.* Oxford: Clarendon Press, 1970.

An intellectual biography stressing d'Alembert's work in mechanics and his place within the *philosophes'* circle. Argues convincingly that d'Alembert was a Cartesian rationalist whose mathematics was rooted in the geometrization of nature. Some discussion of the wave equation and the foundation of his mathematics.

2687. Hankins, Thomas. *Sir William Rowan Hamilton.* Baltimore, London: Johns Hopkins University Press, 1980.

Hankins skillfully weaves together personal, social, intellectual and scientific aspects of Hamilton's life. His chapter on Hamilton's principle and the optical-mechanical analogy discusses the importance this had for Schrödinger's work in wave mechanics. The background to Hamilton's discovery of the quaternions is also very interesting.

2688. Hawkins, Thomas. *Lebesgue's Theory of Integration: Its Origins and Development.* New York: Chelsea, 1970. Second edition 1975.

Now a classic in the historiography of integration theory starting with Riemann's integral and ending with the Lebesgue-Stieltjes integral. Chapters 4–6 and the Epilogue concern the development of measure and integration from 1900 to 1915. Beginning with Borel's theory of measure, these chapters culminate in the Lebesgue integral, its applications (especially the Riesz-Fischer Theorem), and Radon's extension of measure to more general spaces.

2689. Hayman, Walter K. "Nevanlinna Theory 1945-1995". In *16th Rolf Nevanlinna Colloquium.* Edited by Ilpo Laine. Berlin: de Gruyter, 1996, 1-11.

On recent progress in function theory in the direction of the influential Finnish analyst Nevanlinna.

2690. Hellinger, E. "Hilbert's Arbeiten ueber Integralgleichungen und unendliche Gleichungssysteme". In D. Hilbert's *Gesammelte Abhandlungen.* Vol. 3. Berlin: Springer, 1935, 94–145.

A short introduction discusses the work of Sturm and Liouville, the integral equation theory of Volterra and Fredholm, and the work of

Poincaré and Hill on infinite determinants. This is followed by a thorough examination of Hilbert's work and related efforts by the author, Toeplitz, Riesz, Weyl, von Neumann, Friedrichs, Wintner, Banach, Kneser, Courant, et al.

2691. Hellinger, Ernst, and Otto Toeplitz. "Integralgleichungen und Gleichungen mit unendlich vielen Unbekannten". In *Encyklopädie der Mathematischen Wissenschaften* II. C. 13. 1928, 1335-1616.

Still a very valuable first-hand report on the early history of integral equations and operator theory, especially of the Hilbert school.

2692. Herbert, Dieter. *Die Entstehung des Tensorkalküls. Von den Anfängen in der Elastizitätstheorie bis zur Verwendung in der Baustatik*. Stuttgart: F. Steiner Verlag, 1991, 318 pp.

2693. Hewitt, E., and R. Hewitt. "The Gibbs-Wilbraham Phenomenon: An Episode in Fourier Analysis". *Archive for History of Exact Sciences* 21 (1979), 129–160.

Discusses the mathematics as well as the history behind this curious subject in the history of Fourier analysis.

2694. Hille, Einar. *Classical Analysis and Functional Analysis: Selected Papers.* Vol. 11. Edited by Robert R. Kallman. (Mathematicians of Our Time.)

Has 47 selected papers of the Swedish-American analyst E. Hille (1894-1980), among them a valuable autobiographical one. At the end of the volume each paper gets a commentary by a specialist.

2695. Hofmann, Joseph E. *Leibniz in Paris, 1672–1676*. Translated by A. Prag and D. T. Whiteside. Cambridge: Cambridge University Press, 1974.

See item 2170.

2696. Hofmann, Joseph E. "Johann Bernoulli, der Propagator der Infinitesimalmethoden". *Praxis Mathematica* 9 (1967), 209–212.

See item 2239.

2697. Hofmann, Joseph E. "Ueber Jakob Bernoulli's Beiträge zur Infinitesimalmathematik". *L'Enseignement Mathématique* 2 (1956), 61–171.

See items 2112, 2238.

2698. Hofmann, Joseph E. "Aus der Frühzeit der Infinitesimalmethoden: Auseinandersetzung um der algebraischen Quadratur algebraischer

Kurven in der zweiten Hälfte des 17. Jahrhunderts". *Archive for History of Exact Sciences* 2 (1965), 271–343.

Traces the early history of the problem of determining conditions for the integration of an algebraic function by means of algebraic functions. Gives detailed analysis of the contributions of Leibniz, Tschirnhaus, Johann Bernoulli, Craig, et al.

2699. Hofmann, Joseph E.. *Ausgewählte Schriften.* Edited by Ch. J. Scriba. Hildesheim: Georg Olms, 1990. 2 vols.

Contains among other work many articles by Hofmann on the history of analysis, e.g. the dispute between Newton and Leibniz on the invention of the calculus.

2700. Horvath, Jean [Janos]. "L'oeuvere mathématique de Marcel Riesz". *Cahiers du Séminaire d'Histoire des Mathématiques* 3 (1982), 83-121; 4 (1983), 1-59.

Discusses the work of the well-known Hungarian mathematician M. Riesz (1886-1969) in summability, Fourier analysis etc.

2701. Houzel, C. "Fonctions elliptiques et intégrales abéliennes". In *Abrégé d'histoire des mathématiques, 1700–1900.* Edited by J. Dieudonné. Paris: Hermann, 1978, vol. II, 2–113.

Thorough survey, divided for convenience into 24 subdivisions reflecting different aspects of the mathematics, densely written but full of information on the problems as seen and solved during the nineteenth century.

2702. Huke, A. "An Historical and Critical Study of the Fundamental Lemma in the Calculus of Variations". In *University of Chicago Contributions to the Calculus of Variations*, Vol. 1. Chicago: Chicago Unviersity Press, 1930, 45–160.

Discusses the lemma and early proofs (1823–1870) attempted by Dirksen, Sarrus, Todhunter, et al. The first modern proof was by Heine (1870), followed by du Bois-Reymond, Weierstrass, Zermelo, Kneser, Landau, et al. The problem was modified by du Bois-Reymond and proved in this form by Hilbert and several others. Analogues of the fundamental lemma were established by Haar and Schauder.

2703. Israel, Giorgio. "The Poincaré-Volterra Theorem: A Significant Event in the History of the Theory of Analytic Functions". *Historica Mathematica* 11 (1984), 161-192.

On the history of the theorem as reflected in the correspondence between Volterra, Vivanti, and Cantor.

2704. Israel, Giorgio. "Determinism and the Theory of Ordinary Differential Equations". *Physis* Nuova Seria 28 No. 2 (1991), 305-358. In Italian.

On the relations between philosophy, hereditary mechanics, and mathematics (Picard, Volterra etc.) in late 19th century.

2704.1. Jahnke, Hans Niels. "Motive und Probleme der Arithmetisierung der Mathematik in der ersten Hälfte des 19. Jahrhunderts—Cauchys Analysis in der Sicht des Mathematikers Martin Ohm". *Archive for History of Exact Sciences* 37 (1987), 101-182.

Motives and problems of the arithmetization of mathematics in the first half of the 19th century. Cauchy's analysis seen by the mathematician Martin Ohm.

2705. Jahnke, Hans Niels, ed. *Geschichte der Analysis*. Heidelberg: Spektrum Akademischer Verlag, 1998.

Overviews on history separate fields of analysis by 13 authors.

2706. Jarník, V. *Bolzano and the Foundations of Mathematical Analysis*. Prague: Society of Czechoslovak Mathematicians and Physicists, 1981.

Translations of papers in Bolzano's contributions to the foundations of analysis, function theory, and his definition of a continuous, nowhere-differentiable function. Illustrated and with an introduction by J. Folta.

2707. Jensen, C. "Pierre Fermat's Method of Determining Tangents of Curves and Its Applications to the Conchoid and the Quadratrix". *Centaurus* 14 (1969), 72–85.

An attempt to reconstruct Fermat's incomplete solution to the problem of constructing tangents to these curves.

2708. Jourdain, P. E. B. "The Theory of Functions with Cauchy and Gauss". *Biblioteca Mathematica* 3 (1905), 190–207.

Considers Cauchy's 1814 memoir on definite integrals with regard to the origin of his treatment of continuity, imaginary numbers, and the theory of complex integration. This work is contrasted with Gauss's investigations on the integration of functions of a complex variable.

2709. Jourdain, P. E. B. "The Origins of Cauchy's Conception of the Definite Integral and of the Continuity of a Function". *Isis* 1 (1913), 661–703.

The evolution of the function concept and continuity is traced from the vibrating string problem, through Fourier series, to Cauchy's work. A broad, non-technical account that discusses the contributions of Bolzano and De Morgan, and stresses Fourier's work as paving the way to a rigorous, pure mathematics.

2710. Juškevič, Adolf P. “Gottfried Wilhelm Leibniz und die Grundlagen der Infinitesimalrechnung”. *Studia Leibnitiana* 2 (1969), 1–19.

Emphasis is given to Leibniz’s facility in developing useful symbols, as well as to his views on infinitesimals.A French version appears in *Organon* 5 (1968), 153–168.

2711. Kahane, J.-P. “Leopold Fejér et l’analyse mathématique au début du XXe siècle”. *Cahiers du Séminaire d’Histoire des Mathématiques* 2 (1981), 67–84.

Evaluates the significance of Fejér’s work and provides a bibliography.

2712. Kahane, Jean-Pierre. “A Century of Interplay between Taylor Series, Fourier Series and Brownian Motion”. *Bulletin of the London Mathematical Society* 29 No. 3 (1997), 257-279.

Follows the revival of Fourier and Taylor series after 1900, especially with the introduction of randomness and lacunarity and the rise of harmonic analysis.

2713. Kahane, Jean-Pierre. “Leopold Fejer et l’analyse mathématique au debut du XXe siécle”. *Cahiers du Séminaire d’Histoire des Mathématiques* 2 (1981), 67-84.

Discusses the important work of the Hungarian mathematician in Fourier analysis, operator theory, and interpolation.

2714. Kaluza, Roman. *Through a Reporter’s Eyes: the Life of Stefan Banach.* Basel: Birkhäuser, 1996.

A lively account of Stefan Banach’s life (1892-1945), one of the legendary figures of modern mathematics, written by a non-mathematician. Translated from the Polish original (Warsaw, 1992).

2715. Katz, Victor J. “Differential Forms - Cartan to De Rham”. *Archive for History of Exact Sciences* 33 (1985), 321-336.

A continuation of an earlier paper in *Historia Mathematica*, 8, now discussing differential forms in the abstract contexts of the 20th century.

2716. Katz, Victor J. “Ideas of Calculus in Islam and India”. *Math. Mag.* 68 No. 3 (1995), 163-174.

Describes in detail Ibn al Haytham’s method of derivation of the sums of powers of integers and its application by Indian mathematicians to power series of sine and cosine long before anybody in the West considered power series.

2717. Kitcher, P. “Fluxions, Limits, and Infinite Littleness: A Study of Newton’s Presentation of the Calculus”. *Isis* 64 (1973), 33–49.

Argues that Newton’s use of fluxions, infinitesimals, and the method of prime and ultimate ratios, should be understood as responses to distinct mathematical needs. Thus the universality of Newton's genius can be seen as reflecting the complexities of the mathematics of his day.

2718. Kjeldsen, Tinne Hoff. "The Early History of the Moment Problem". *Historica Mathematica* 20 (1993). 19-44.

From the origins of the problem in the work of Stieltjes in 1892 through the papers of Hausdorff, Grommer, Hamburger, Nevanlinna, and M. Riesz.

2719. Klein, F. *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert.* Berlin: Springer-Verlag, 1926–1927. 2 vols. Reprinted in 1 vol. New York: Chelsea, 1967.

This classic work is by now rather dated, but still offers insights into the period that give it an enduring value. The chapter on Gauss borders on hagiography, but is at the same time highly suggestive as an interpretive key for the development of mathematics throughout the 19th century. The treatment of work by Cauchy, Dirichlet, Abel, and C. G. Jacobi is somewhat brief, whereas Riemann and Weierstrass are explored in detail. Klein's geometric outlook predominates throughout, and this has somewhat influenced his choice of subject matter. Thus analysis is largely subordinated to the development of mechanics and mathematical physics. Some topics (e.g., elliptic and automorphic functions) do, however, receive considerable attention. See also items 2299 and 3047.

2720. Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972.

No topic receives as much attention in this book as does analysis. The chapters on "Mathematiziation of Science" and "The Creation of Calculus" go hand in hand. Ordinary and partial differential equations occupy four chapters (one each for both the 18th and 19th centuries), while the calculus of variations comprises two (again one each for the 18th and 19th centuries). Other chapters include "Complex Variables", "Integral Equations", "Real Variables", and "Functional Analysis". See also items 902, 2225, 2300, 2345, 3029, 3812.

2721. Knobloch, Eberhard, and David. E. Rowe, eds. *The History of Modern Mathematics.* Vol. III. *Images, Ideas, and Communities.* Boston etc.: Academic Press, 1994.

Contains articles on the history of analysis by P. Ullrich (Riemann removable singularity theorem, Laurent expansion).

2722. Kolman, A. *Bernard Bolzano.* Berlin: Akademie Verlag, 1963.

Originally published as Ernest Kol′man, *Bernard Bol′tsano* (Moscow: Akademii Nauk SSSR, 1955, 223 pp.), with illustrations and portraits.Includes bibliographies.

2723. Kolmogorov, Andrej N., and Adolf P. Youschkevitch, eds. *Mathematics of the 19th Century. Geometry, Analytic Function Theory.* Basel: Birkhäuser, 1996.

This is a translation by R. Cooke of the Russian original from 1981. It has articles on the history of geometry (by B. L. Laptev and B. A. Rosenfeld), and on Analytic Function Theory (by A. I. Markushevich).

2724. Kolmogorov, Andrej N., and Adolf P. Yushkevich, eds. *Mathematics of the 19th Century. Function Theory According to Chebyshev, Ordinary Differential Equations, Calculus of Variations, Theory of Finite Differences.* Basel: Birkhäuser, 1998.

This is a translation by R. Cooke of the Russian original from 1987 which is dedicated to four significant chapters of real variable analysis. It contains historical articles by N. I. Akhiezer (approximations), S. S. Demidov (ordinary differential equations, very comprehensive), A. V. Dorofeeva (Calculus of Variations), S. S. Petrova and A. D. Solov'ev (finite differences).

2725. König, Gert, ed. *Konzepte des mathematisch Unendlichen im 19.Jahrhundert. Beiträge zu der interdisziplinären Tagung "Wissen und Gesellschaft", Bochum 1986.* Vol. 5. (sr Studien zur Wissenschafts-, Sozial- und Bildungsgeschichte der Mathematik.) Göttingen: Vandenhoeck & Ruprecht, 1990.

Concepts of mathematical infinity in the 19th century discussed in articles by W. Bonsiepen, P. Dugac, I. Grattan-Guinness, H. N. Jahnke, A. Klaucke, D. Laugwitz, A. Moretto, M. Otte, G. Schubring, and D. Spalt

2726. Koppelman, Elaine. "The Calculus of Operations and the Rise of Abstract Algebra". *Archive for History of Exact Sciences* 8 (1971), 155–242.

See items 2569, 2569.

2727. Kracht, Manfred, and Erwin Kreyszig. "E. W. von Tschirnhaus: His Role in Early Calculus and His Work and Impact on Algebra". *Historica Mathematica* 17 (1990), 16-35.

The interest of the paper lies in the fact that it treats Tschirnhaus, the associate of Leibniz, as an individual.

2728. Krazer, A. "Zur Geschichte des Umkehrproblems". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 18 (1909), 44–75.

An accurate account of the work of Euler, Gauss, Abel, and C. G. Jacobi on the inversion of elliptic integrals.

2729. Langer, R. E. "Fourier Series: The Genesis and Evolution of a Theory". *American Mathematical Monthly* 54 Part 2 (1947), 1–81.

A leisurely exposition of the subject's development beginning with the vibrating string problem, through Fourier's study of heat diffusion, to the study of characteristic values, orthogonality conditions, Green's function, and the formal Fourier series representation of an arbitrary function.

2730. Laugwitz, Detlef. "Definite Values of Infinite Sums: Aspects of the Foundations of Infinitesimal Analysis around 1820". *Archive for History of Exact Sciences* 39 (1989), 195-245.

Focuses on Cauchy's work, especially on his notions of convergence and infinitesimals.

2731. Laugwitz, Detlef. *Bernhard Riemann. 1826-1866. Wendepunkte in der Auffassung der Mathematik.* Vol. 10. (Vita Mathematica.) Basel: Birkhäuser, 1996. Translated as *Bernhard Riemann, 1826-1866: Turning Points in the Conception of Mathematics.* Translator Abe Shenitzer. Boston: Birkhäuser, 1999.

The first comprehensive book on Riemann with emphasis on function theory. Riemann's more advanced ideas are discussed without being too technical.

2732. Lebesgue, Henri. "À propos de quelques travaux mathématiques récents". *L'Enseignement Mathématique* 17 (1971), 1–48.

Based on unpublished notes from 1905. Discusses the development of real variable theory including contributions of Euler, Fourier, Cauchy, Peano, Cantor, Dini, Lipschitz, Arzelà, Osgood, C. Jordan, Baire, and du Bois-Reymond.

2733. Lebesgue, Henri. *Notice sur les travaux scientifiques de M. Henri Lebesgue.* Toulouse: Edouard Privat, 1922.

A short summary of the development of real variable theory during the 19th century is followed by chapters detailing Lebesgue's work on measure theory and integration, representation of functions by infinite series, the problems of Dirichlet and Plateau in the calculus of variations, topology, geometry, and miscellaneous other areas.

2734. Leibniz, Gottfried Wilhelm von. *De quadratura arithmetica circuli ellipseos et hyperpolae cujus corollarium est trigonometria sine tabulis*, edited and commented by Eberhard Knobloch. (Abhandlungen der Akademie der Wissenschaften in Göttingen, mathematisch-physikalische Klasse (3), No. 43.) Göttingen: Vandenhoeck & Ruprecht, 1993.

2735. Levitan, B. M. "Outline of the History of Almost Periodic Functions". *Istoriko-matematicheskie Issledovanija* 25 (1980), 156-166. In Russian.

Discusses papers by J. von Neumann, N. N. Bogoljubov and others which connect to Harald Bohr's foundation of the theory in the 1920s.

2736. Lévy, P. et al. "La vie et l'oeuvre de J. Hadamard". *L'Enseignement Mathématique* 13 (1967), 1–72.

Articles covering Hadamard's work in functional analysis (Lévy), function theory (Mandelbrojt), number theory (Mandelbrojt), partial differential equations (Malgrange), and geometry (Malliavin), plus a complete bibliography.

2737. Lichtenstein, Leon. *Festkolloquium aus Anlaß der hundertsten Wiederkehr des Geburtstages von Leon Lichtenstein*. Vol. 29, No. 1 of *Wissenschaftliche Zeitschrift Karl-Marx-Universität Leipzig, Math.-naturwissenschaftliche Reihe*, 1980.

Papers from a conference on the occasion of the centenary of Lichtenstein's birth. Includes articles by H. Becker on Lichtenstein's work in analysis, and by H. Schubert on Lichtenstein's work in mechanics.

2738. Lützen, Jesper. "Funktionsbegrebets udvikling fra Euler til Dirichlet". *Nordisk Matematisk Tidskrift* 25/26 (1978), 4–32.

Argues that with Euler the concept of function acquired its central position in mathematics. Although a general definition of function as a correspondence had been published as early as 1755, in practice functions were always taken to be analytic expressions. This apparent contradiction is explained by the 18th-century belief in the generality of the calculus.

2739. Lützen, Jesper. "Heaviside's Operational Calculus and the Attempts to Rigorise It". *Archive for History of Exact Sciences* 21 (1979), 161–200.

Surveys Heaviside's achievement, and looks at attempts to formalize it either in terms of the theory of integral transforms or as an abstract algebraic theory. The connections with Schwartz's theory of distributions are also discussed, as are the origins of that theory in J. Lützen, *The Prehistory of the Theory of Distributions*, Dissertation, Aarhus University, Denmark, 1979. See also items 2909, 2977.

2740. Lützen, Jesper. *Joseph Liouville 1809-1882: Master of Pure and Applied Mathematics*. Vol. 15. (Studies in the History of Mathematics and Physical Sciences.) New York etc.: Springer, 1990, 884 pp.

This very comprehensive book gives both an account of Liouville's life and career, and of his mathematics. It uses partly unpublished manuscripts by Liouville and other archival material. Reviewed by Frank Smithies in **MR** 91h:01067. See also item 2705 for another article by Lützen.

2741. Lysenko, V. I. "Differential Equations in the Work of A. J. Lexell" *Istoriko-matematicheskie Issledovanija* 32/33 (1990), 39-52. In Russian.

On the work of the collaborator and successor of Euler in differential equations and differential forms.

2742. Maanen, Jan A. van. "The Refutation of Longomontanus' Quadrature by John Pell". *Annals of Science* 43 (1986), 315-352.

On Pell's refutation, during his stay in the Netherlands 1643-1652, of a quadrature of the circle published by the Danish astronomer and mathematician Longomontanus in 1644. See also item 2705 for another article by Maanen.

2743. Mackey, George. *The Scope and History of Commutative and Noncommutative Harmonic Analysis.* Vol. 5. (History of Mathematics.) Providence, R.I. and London: American Mathematical Society and London Mathematical Society, 1992.

A very comprehensive and very technical history, written by a prominent mathematician and contributor to the field in question.

2744. Manning, K. R. "The Emergence of the Weierstrassian Approach to Complex Analysis". *Archive for History of Exact Sciences* 14 (1975), 297–383.

Concentrates on Gudermann's approach to function theory, which in turn is connected to Lambert's work on hyperbolic functions. Gudermann was Weierstrass's only significant mathematics teacher and strongly emphasized the use of power series in the study of elliptic functions; it is argued that this influenced Weierstrass's approach to complex analysis. The paper also contains a useful annotated bibliography.

2745. Markushewitsch, A. I. *Skizzen zur Geschichte der analytischen Funktionen.* Berlin: VEB Deutscher Verlag der Wissenschaften, 1955, viii + 139 pp., especially pp. 1–45.

Eighteenth-century achievements are quite extensively discussed. They are viewed as ingredients and preliminaries of a more systematic development of the theory of analytic functions in the 19th century.

2746. Manning, Kenneth R. "The Emergence of the Weierstrassian Approach to Complex Analysis". *Archive for History of Exact Sciences* 14 No. 4 (1975), 297-383.

Investigates the influence of Weierstrass's teacher Christoph Gudermann (1798-1851) in Münster on Weierstrass, especially on his work from 1840 through 1842.

2747. Mathews, Jerold. "William Rowan Hamilton's Paper of 1837 on the Arithmetization of Analysis". *Archive for History of Exact Sciences* 19 (1978), 177–200.

Examines the content of Hamilton's paper and offers several reasons for its lack of influence on mathematicians of his day. See also item 2326.

2748. Mawhin, Jean. "Integration and the Fundamental Theory of Ordinary Differential Equations: A Historical Sketch".In *Constantin Caratheodory: An International Tribute.* Vol. II Edited by Th. Rassias. 1991, 828-849.

Author presents the historical evolution, from the contributions of Euler to the present, of the Cauchy problem for ordinary differential equations putting emphasis on the relation between the concept of the solution and the concept of the integral.

2749. Malet, Antoni. "Barrow, Wallis, and the Remaking of Seventeenth Century Indivisibles". *Centaurus* 39 No.1 (1997), 67-92.

Work of K. Andersen and F. Gandt has shown that Cavalieri's indivisibles were misrepresented during the second half of the 17th century. Author shows by the example of I. Barrow and J. Wallis how, in fact, indivisibles were dropped in favour of infinitesimals.

2750. Masani, Pesi R. *Norbert Wiener 1894-1964.* Vol. 5. (Vita Mathematica.) Basel etc.: Birkhäuser, 1990.

A comprehensive first-hand account from a student and collaborator of Wiener's. Much correspondence is included and the author does not conceal his admiration and subjectivity.

2751. McHugh, J. A. M. "An Historical Survey of Ordinary Differential Equations with a Large Parameter and Turning Points". *Archive for History of Exact Sciences* 7 (1970/1971), 277–324.

See item 2911.

2752. McShane, Edward J. "The Calculus of Variations from the Beginning through Optimal Control Theory". *SIAM Journal on Control and Optimization* 27 (1989), 916-939.

Starting with Weierstrass and McShane's own work around 1940 on the Bolza problem the articles focuses on the contribution by L. S. Pontryagin and his school. Republication of an article from 1977.

2753. Medvedev, Fedor A., ed. *Frantsuzskaya Shkola Teorii Funksii i Mnozhestv, na Rubezhe XIV–XX VV.* Moscow: Nauka, 1976.

†The French School of the Theory of Functions and Sets at the Turn of the XIX–XX Centuries† centers around the work of Borel, Baire, and Lebesgue. To a lesser extent it also considers Fréchet, Denjoy, and others. The impact of the French school on mathematics in Italy, England, Russia, and other countries is also considered.

2754. Medvedev, Fedor A. "On the History of the Notion of Uniform Convergence of Series". *Istoriko-matematicheskie Issledovanija* 19 (1974), 75-93. In Russian.

Dealing with the original work by Ph. L. Seidel E. Heine, K. Weierstrass and others.

2755. Medvedev, Fedor A. *Scenes from the History of Real Functions.* Vol. 7. (Science Networks: Historical Studies.) Basel etc.: Birkhäuser, 1991.

Translation of the classic Russian original from 1975, which was followed by further monographs (history of axiom of choice, French school of function theory) yet to be translated into English. The bibliography contains several of them.

2756. Mittag-Leffler, G. "An Introduction to the Theory of Elliptic Functions". *Annals of Mathematics* 24 (1922–1923), 271–351.

A useful introduction to the subject as it developed after the fundamental discoveries of Abel and C. G. Jacobi. The lion's share of the attention, however, is devoted to Weierstrass's work.

2757. Monna, A. F. "The Concept of Function in the 19th and 20th Centuries, in Particular with Regard to Discussions between Baire, Borel and Lebesgue". *Archive for History of Exact Sciences* 9 (1972), 57–84.

Chiefly devoted to the discussions of Baire, Borel, and Lebesgue on the definition of a function, and on when a function is known. The roots of this debate are traced from the vibrating string problem via Dirichlet and Riemann. Compare with the A. P. Youschkevitsch article in the same journal, "The Concept of Function up to the Middle of the 19th Century", item 2829.

2758. Monna, A. F. *Dirichlet's Principle: A Mathematical Comedy of Errors and Its Influence on the Development of Analysis.* Utrecht: Oosthoek, Scheltema, and Holkema, 1975.

Somewhat dated by the work of Thomas Archibald and others but still a good introduction. Traces the uses and criticisms of Dirichlet's principle by Gauss, W. Thomson (Lord Kelvin), Dirichlet, Riemann, Weierstrass, and Hilbert, with a consideration of the modern functional analytic view. Generous quotations from original sources.

2759. Neuenschwander, E. "The Casorati-Weierstrass Theorem". *Historia Mathematica* 5 (1978), 139–166.

The Casorati-Weierstrass theorem clarifies the nature of an essential singular point of a complex function (of a single variable), which was not at first understood. Casorati reached it in 1868 as part of a deliberate attempt to give a rigorous treatment of function theory; Weierstrass reached it independently somewhat earlier. The Russian mathematician Sokhotskii also found the result independently at the same time.

2760. Neuenschwander, Erwin. "Der Nachlaß von Casorati (1835-1890) in Pavia". *Archive for History of Exact Sciences* 19 (1) (1978), 1-89.

Investigates the papers left by the Italian function theorist Felice Casorati in Pavia.

2761. Neuenschwander, Erwin. *Riemanns Einführung in die Funktionentheorie: Eine quellenkritische Edition seiner Vorlesungen mit einer Bibliographie zur Wirkungsgeschichte der Riemannschen Funktionentheorie.* (Abhandlungen der Akademie der Wissenschaften in Göttingen. Mathematisch-physikalische Klasse, 44 (3).) Göttingen: Vandenhoeck & Ruprecht, 1996.

Transcription of E. Abbe's notes (1861), facsimile reproduction of Riemann's preparation notes, and a list of 2,000 works that influenced Riemann.

2762. Oberschelp, A. "Die Entwicklung der Leibnizschen Idee der unendlich kleinen Grössen in der modernen Mathematik". *Studia Leibnitiana Supplementa* 2 (1969), 27–33.

Emphasizes Leibniz's contention that infinitesimals cannot be compared with finite numbers, and relates this to a consideration of A. Robinson's nonstandard analysis.

2763. Otte, Michael, and Marco Panza, eds. *Analysis and Synthesis in Mathematics. History and Philosophy.* Vol. 196. (Boston Studies in the Philosophy of Science.) Dordrecht: Kluwer, 1997.

Its articles on the history of analysis include J. Dhombres (Vieta and Fourier), C. Fraser (Euler), G. Israel (Descartes), M. Panza (sources in antiquity), E. Pasini (Leibniz), and E. D. Sylla (Jacob Bernoulli).

2764. Ovaert, J. L. "La thèse de Lagrange et la transformation de l'analyse". *Philosophie et calcul de l'infini.* Paris: Maspero, 1976, 157–200.

Lagrange's formal power series approach to analysis is compared with the work of his predecessors, L'Hospital and Maclaurin. Includes appendices outlining the contents of their calculus texts and reproducing the sections pertaining to the foundations of these three systems.

2765. Panza, Marco. *La forma della quantita. Analisi algebrica e analisi superiore: il problema dell'unita della matematica nel secolo dell'illuminismo, Tome I, II.* (Cahiers d'Histoire et de Philosophie des Sciences, Nouvelle Serie, 38, 39.) Paris: Société Française d'Histoire de de Philosophie des Sciences et des Techniques, 1992.

The form of quantity. Algebraic analysis and higher analysis: the problem of the unity of mathematics in the age of the Enlightenment.

2766. Paplauskas, A. B. "The pre-Newtonian Development of the Theory of Infinite Series". *Istoriko-matematicheskie Issledovanija* 20 (1975), 257-281. In Russian.

A sequel to previous articles by the author in the same journal (1973/74) and a book (Moskva: Nauka, 1966) on the same topic.

2767. Parkinson, G. H. R. "Science and Metaphysics in the Leibniz-Newton Controversy". *Studia Leibnitiana Supplementa* 2 (1969), 79–112.

Stresses that the differences between Newton and Leibniz were primarily philosophical. Whereas Newton proceeded by induction, Leibniz developed his own ideas as early as 1703–1705 in conjunction with objections to Locke's arguments in his *New Essays*.

2768. Peiffer, Jeanne. "Pierre Varignon lecteur de Leibniz et de Newton." *Studia Leibnitiana, Suppl.*, 27 (1990), 244-266.

According to Johann Bernoulli Varignon was "not an original inventor, but a qualified commentator." Article illustrates this by considering the problem of the reception of the calculus.

2769. Pepe, Luigi. "The Infinitesimal Calculus in Italy at the Beginning of the 18th Century". *Boll. Stor. Sci. Mat.* 1 No. 2 (1981), 43-101. In Italian.

2770. Pepe, Luigi. "Three 'First Editions' and One Unpublished Introduction to the Theory of Analytic Functions of Lagrange." *Boll. Stor. Sci. Mat.* 6 No. 1 (1986), 17-44. In Italian.

Compares Lagrange's publications with his unpublished lectures at the École Polytechnique in 1797.

2771. Pepe, Luigi. "Giuseppe Vitali and Real Analysis". *Rend. Sem. Mat. Fis. Milano.* 54 (1984), 187-201. In Italian.

On Vitali's career and his publication in 1905 of an example of a non-measurable set.

2772. Pesin, I. M. *Classical and Modern Integration Theories.* New York: Academic Press, 1970.

A useful reference, giving a bird's-eye view of developments from Cauchy to Lebesgue and beyond. Generally expository, but with occasional proofs, the work of Borel, Lebesgue, Young, Stieltjes, Denjoy and Khinchin, Perron, and Daniell form the main body of the book.

2773. Petrov, Yuri P. "From the History of Variational Calculus and of the Theory of Optimal Processes". *Istoriko-matematicheskie Issledovanija* 32/33 (1990), 53-74. In Russian.

Contains an outline of the history of variational calculus and the theory of optimal processes.

2774. Petrova, Svetlana S. "Heaviside and the Development of the Symbolic Calculus". *Archive for History of Exact Sciences* 37 (1987), 1-23.

Treats the symbolic or operational method pioneered by Oliver Heaviside in solving certain types of ordinary and partial differential equations.

2775. Petrova, Svetlana S., and Alexander D. Solov′ev. "The Origin of the Method of Steepest Descent". *Historica Mathematica* 24 (1997), 361-375.

Authors show that the method, also known as the saddle-point method for the asymptotic estimate of integrals of analytic functions, dates back to Cauchy.

2776. Pier, Jean-Paul. *L'analyse harmonique. Son développement historique.* Paris: Masson, 1990.

Gives a history of harmonic analysis from the beginning of the theory of topological groups in the 1930s until recently. The bibliography has 900 titles.

2777. Pier, Jean-Paul. *Histoire de l'intégration. Vingt-cinq siècles des mathématiques.* Paris: Masson, 1996.

Covers integration from Hippocrates and Archimedes to Henstock and Kurzweil, including nonstandard methods etc. Contains 1,200 titles in the bibliography.

2778. Pier, Jean-Paul, ed. *Development of Mathematics 1900–1950.* Basel etc.: Birkhäuser, 1994.

Collections includes articles on the history of analysis mostly by working mathematicians: G. Fichera (functional analysis), W. K. Hayman (function theory),J.-P. Kahane (Taylor series and Brownian motion),J. Mawhin (boundary value problems in ordinary differential equations), L. Nirenberg (partial differential equations), J.-P. Pier (integration and measure).

2779. Pierpont, J. "Mathematical Rigor, Past and Present". *Bulletin of the American Mathematical Society* 34 (1928), 23–53.

Illustrates the relativism of mathematical rigor by surveying accepted standards in different periods: calculus in the 17th and 18th centuries, Cauchy and Weierstrass on analysis, Kronecker on algebra, Cantor, Dedekind, and Poincaré on set theory, and Peano, Hilbert, Russell, and Frege on mathematical logic are among the examples considered.

2780. Plancherel, M. "Le développement de la théorie des séries trigonométriques dans le dernier quart de siècle". *L'Enseignement Mathématique* 24 (1924–1925), 19–58.

An update on progress in this field supplementing H. Burkhardt's (see item 2607). Topics include Riesz-Fischer Theorem, plus work of Lebesgue, Hardy and Littlewood, Cesaro, L. Fejér, W. H. Young, de la Vallée-Poussin, et al.

2781. Porter, T. I. "A History of the Classical Isoperimetric Problem". *University of Chicago Contributions to the Calculus of Variations* 2 (1933), 475–517.

Begins with origins and early proofs in antiquity. Geometric proofs of the isoperimetric property of the circle were accomplished by J. Steiner, Blaschke, and Bonneson. Hurwitz gave a proof using Fourier series, and Weierstrass, Bolza, Tonelli, and Bonneson gave proofs using the calculus of variations. A bibliography of work on the problem is included.

2782. Prekopa, Andras. "On the Development of Optimization Theory". *American Mathematical Monthly* 87 (1980), 527-542.

Discusses the history of both linear and nonlinear optimization, especially origins in the work of Fourier, Gauss, Farkas, Hamel, Kuhn, Tucker etc.

2783. Rassias, Themistocles M., ed. *The Problem of Plateau. A Tribute to Jesse Douglas and Tibor Rado.* London: World Scientific Publishing, 1992.

Includes an article by E. Kreyszig (pp.18-32) on T. Rado and his main mathematical work.

2784. Reiff, R. A. *Geschichte der unendlichen Reihen.* H. Lauppsche Buchhandlung, 1889. Reprinted Wiesbaden: Martin Sändig, 1969.

A very useful survey of the history of summation of series from the 17th century through 1850. The 18th century is characterized as the period of formal treatment of series. See item 2087.

2785. Riesz, F. "L'évolution de la notion d'integrale depuis Lebesgue". *Annales de l'Institut Fourier* 1 (1949), 29–42.

This short paper reflects a lecture Riesz delivered in Paris, and also at Grenoble, in the same year. He traces the development of the integral from Lebesgue, including developments made by Fatou, Stieltjes, Young, Perron, Lusin, Egoroff, Denjoy, de la Vallée-Poussin, Daniell, Carathéodory, and Stone, among others. No bibliography.

2786. Ross, B. "The Development of Fractional Calculus 1695–1900". *Historia Mathematica* 4 (1977), 75–89.

Beginning with the work of l'Hospital and Leibniz, the author proceeds to consider the contributions of Euler, Laplace, Abel, Liouville, Riemann, Sarim, and Letnikov, among others. He ends with a remark on Heaviside's operators.

2787. Rowe, David E. "Klein, Mittag-Leffler, and the Klein–Poincaré Correspondence of 1881-1882". In *Amphora: Festschrift fr̈*

Hans Wussing zu seinem 65.Geburtstag. Edited by S. Demidov et al. Basel etc.: Birkhäuser, 1992, 567-618.

On the correspondence between F. Klein and H. Poincaré over automorphic functions and uniformization.

2788. Sachse, A. "Essai historique sur la représentation d'une fonction arbitraire d'une seule variable par une série trigonométrique". *Bulletin des Sciences Mathḿatiques* 4 (1880), 43–64, 83–112.

Discusses work of Riemann, Dirichlet, du Bois-Reymond, Weierstrass, Heine, Lipschitz, Schwartz, et al.

2789. Schappacher, Norbert, and Erhard Scholz, eds. "Oswald Teichmüller - Leben und Werk". *Jahresbericht Deutsche Mathematikervereinigung* 94 No. 1 (1992), 1-39.

Life and work of the brilliant function theorist and ardent Nazi Teichmüller. Includes contributions by the editors and by K. Hauser, F. Herrlich (Teichmüller and Riemann surfaces), M. Kneser, and H. Opolka.

2790. Schlesinger, L. "Bericht ueber die Entwicklung der Theorie der linearen Differentialgleichungen seit 1865". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 18 (1909), 133–266.

See item 2917.

2791. Schlissel, Arthur. "The Development of Asymptotic Solutions of Linear Ordinary Differential Equations, 1817–1920". *Archive for History of Exact Sciences* 16 (1976/1977), 307–378.

Considers the origins of the theory in work of Carlini, Liouville, Green, Stokes, and Hankel. Poincaré is the central figure, as his contributions made this subject a distinct new branch of modern mathematics. His work is examined along with that of G. D. Birkhoff, Horn, Schlesinger, Tamarkin, and Debye. See also items 2915, 3239.

2792. Scholz, Erhard. "Hermann Grassmanns Analysis in Vektorräumen". *Mathematische Semesterberichte* 31 No. 2 (1984), 177-194.

Points out that Hermann Grassmann not only introduced n-dimensional vector spaces but also discussed the foundations of an analysis in several real variables in them.

2793. Schneider, Ivo. "Der Mathematiker Abraham de Moivre (1667–1754)". *Archive for History of Exact Sciences* 5 (1968/1969), 177–317.

See items 2249, 3687.

2794. Scott, J. F. *The Mathematical Work of John Wallis*. Oxford: Oxford University Press, 1938.

See item 2216.

2795. Scriba, Christoph J. "The Inverse Method of Tangents: A Dialogue Between Leibniz and Newton (1675–1677)". *Archive for History of Exact Sciences* 2 (1964), 113–137.

The author stresses that in this early correspondence the geometric view still predominates. The use of integral tables for the quadrature of curves is recognized by both parties as an important new tool for analysis, but the motivation still comes from classical rather than analytic geometry.

2796. Scriba, Christoph J. "Neue Dokumente zur Entstehungsgeschichte des Prioritätsstreits zwischen Leibniz und Newton um die Erfindung des infinitesimalrechnung". *Studia Leibnitiana Supplementa* 2 (1969), 69–78.

On the basis of manuscripts and letters by J. Gregory and Wallis, it is shown that Wallis and Gregory precipitated the dispute with Leibniz by accusing him of having stolen the calculus from Newton. Wallis was motivated by his anger over an anonymous review written by Leibniz of his *Opera Mathematica* (1695).

2797. Siegmund-Schultze, Reinhard. "Die Anfänge der Funktionalanalysis und ihr Platz im Umwälzungsprozeß der Mathematik um 1900". *Archive for History of Exact Sciences* 26 (1982,) 13-71.

Focuses on the methodical differences of the various early approaches (V. Volterra, E. Schmidt, D. Hilbert, M. Fréchet, S. Pincherle, C. Arzelà, G. Ascoli, and P. Lévy) and the role of set theory in the beginnings of functional analysis.

2798. Siegmund-Schultze, Reinhard. "Eliakim Hastings Moore's 'General Analysis'". *Archive for History of Exact Sciences* 52 (1998), 51-89.

Analyzes Moore's first General Analysis (before 1915) and the reasons for its failure to influence modern functional analysis. See also item 2705 for another article by Siegmund-Schultze.

2799. Sinaceur, H. "Cauchy et Bolzano". *Revue d'histoire des sciences* 26 (1973), 97–112.

The author disputes the claim of Grattan-Guinness that Cauchy plagiarized Bolzano (see item 2677). Instead she attempts to show that Cauchy and Bolzano represent two distinct mathematical traditions: the former being an exponent of mainstream geometry, the latter a precursor of Weierstrassian analytic rigor.

2800. Smail, L. L. *History and Synopsis of the Theory of Summable Infinite Processes.* Eugene: University of Oregon Press, 1925.

This study presents a comprehensive survey of results (to about 1920) on the theory of summability of nonconvergent series and related forms. Beginning with a brief history of the early use of divergent series (pp.

1–3), a summary is given of each memoir, paper, or work dealing with the subject, including important definitions and theorems (without proof), arranged in chronological order from Frobenius (1880) to Takenaka (1923), pp. 4–173. An index of names of authors (pp. 174–175) and an index to important topics of the subject matter are also provided.

2801. Smithies, Frank. *Cauchy and the Creation of Complex Function Theory.* Cambridge: Cambridge University Press, 1997.

The first comprehensive presentation of Cauchy's creation, between 1814 and 1831, of complex function theory. Notations and terminology are cautiously modernized.

2802. Spalt, Detlef. *Vom Mythos der Mathematischen Vernunft. Eine Archäologie zum Grundlagenstreit der Analysis oder Dokumentation einer vergeblichen Suche nach der Einheit der Mathematischen Vernunft.* Darmstadt: Wissenschaftliche Buchgesellschaft, 1981.

Drawing mainly on the examples of nonstandard analysis and Cauchy's work on series of continuous functions, the author polemizes against retrospective rationalist reconstructions of the history of analysis.

2803. Stanton, R. J., and R. O. Wells, eds. *History of Analysis.* (Rice University Studies, 64, nos. 2 & 3.) Houston, Tex.: William Marsh Rice University, 1978.

Proceedings of a Conference on the History of Analysis. Papers on "Mathematics and Society—A Historical View" (F. E. Browder), "The Emergence of Analysis in the Renaissance and After" (S. Bochner), "The Creation of the Theory of Group Characters" (T. Hawkins, see item 2497), and "Harmonic Analysis as the Exploitation of Symmetry" (G. W. Mackey).

2804. Stolz, O. "B. Bolzano's Bedeutung in der Geschichte der Infinitesimalrechnung". *Mathematische Annalen* 18 (1881), 255–279.

Compares approaches of Bolzano and Cauchy, and argues that not only did Bolzano have priority but in important respects he went beyond him. Also shows the connection between Bolzano's ideas and subsequent developments.

2805. Strømholm, P. "Fermat's Methods of Maxima and Minima and of Tangents. A Reconstruction". *Archive for History of Exact Sciences* 5 (1968), 47–69.

Attempts to rehabilitate Wieleitner's thesis that Fermat had no single "method" for finding tangents to curves.

2806. Synowiec, John. "Distributions: The Evolution of a Mathematical Theory". *Historica Mathematica* 10 (1983), 149-183.

Discusses origins in partial differential equations and operational calculus. Has details on potential theory and fractional integration.

2807. Taylor, Angus E. "The Differential: Nineteenth and Twentieth Century Developments". *Archive for History of Exact Sciences* 12 (1974), 355–383.

Treats the definitive formulation of the differential by O. Stolz in 1893, and the development of a differential suitable for functional analysis by M. Fréchet in 1911–1912.

2808. Taylor, Angus E. "A Study of Maurice Fréchet. III. Fréchet as an Analyst, 1909-1930". *Archive for History of Exact Sciences* 37 No.1 (1987), 25-76.

The third in a sequel of articles in the same journal on the founder of the notion of a metric space, Maurice Fréchet.

2809. Tazzioli, Rossana. "The Role of Differential Parameters in Beltrami's Work". *Historica Mathematica* 24 (1997), 25-45.

Beltrami's consideration in 1864 of intrinsic properties in classical and Riemannian differential geometry paved the way for tensor analysis. The paper is a sequel to previous articles by the author on E. Beltrami in *Archive for History of Exact Sciences* 49 (1996) and 46 (1993).

2810. Tazzioli, Rossana. "The Riemann Representation Theorem: Criticism and Interpretation by Schwarz". In *Studies in the History of Modern Mathematics.* Vol I. Edited by U. Bottazzini. *Suppl. Rendiconti Circ. Mat. Palermo.* (2) (1994), 34, 95-132. (Item 2602.)

Discusses objections to Riemann's use of the Dirichlet Principle, especially in the work of H. A. Schwarz and E. B. Christoffel.

2811. Thiele, Rüdiger. *Leonhard Euler.* Vol. 56. (Biographien hervorragender Naturwissenschaftler, Techniker und Mediziner.) Leipzig: Teubner, 1982.

A booklet focusing on the biography and especially Euler's years in Berlin.

2812. Thiele, Rüdiger. "On Some Contributions to Field Theory in the Calculus of Variations from Beltrami to Carathéodory". *Historica Mathematica* 24 (1997), 281-300.

Beltrami and Hilbert traveled the same mathematical route to field theory, but in opposite directions. In the long run, Carathéodory's approach was most successful. See item 2705 for another article by Thiele.

2813. Todhunter, Isaac. *A History of the Calculus of Variations during the Nineteenth Century.* New York: Chelsea, 1962, reprint of the 1861 edition.

Beginning approximately where Woodhouse (item 2229) leaves off. The first half is devoted to the work of Lagrange, Lacroix, Dirksen, Ohm, Gauss, Poisson, Ostrogradsky, Delaunay, Sarrus, Cauchy, Legendre, Brunacci, and C. G. Jacobi. The second deals with the numerous expositors and commentators of the mid-19th century. See Goldstine, items 2081, 2221, for a more recent account.

2814. Toeplitz, O. *Die Entwicklung der Infinitesimalrechnung. Eine Einleitung in der Infinitesimalrechnung nach der genetischen Methode*. Berlin: Springer, 1949.

Based on a lecture course given in 1926, this work was prepared for publication by Gottfried Köthe from an unfinished manuscript that Toeplitz left behind at the time of his death in 1940. The genetic method refers to the analysis of a modern subject by tracing its various roots in the past. This is therefore not intended as a complete and unbiased account of the development of calculus, but rather as an attempt to sketch how the subject came to acquire its present form.

2815. Truesdell, Clifford. "The Influence of Elasticity on Analysis: The Classical Heritage". *Bulletin AMS* New Series 9 (1983), 293-310.

Covers the period which ends approximately in the middle of the nineteenth century. Stresses the work of Euler and Saint-Venant.

2816. Tucciarone, J. "The Development of the Theory of Summable Divergent Series from 1880 to 1925". *Archive for History of Exact Sciences* 10 (1973), 1–40.

Analyzes the early work of Frobenius, Hölder, Cesàro, and Borel from 1880 to 1900 leading to Knopp's recognition of the essential criteria for a theory of divergent series. Further developments by Riesz, Hardy, Toeplitz, Hausdorff, Tauber, and Wiener are considered, and a substantial bibliography is included.

2817. Turnbull, H. W. *The Mathematical Discoveries of Newton*. London, Glasgow: Blackie & Son, 1945.

A short but useful sketch of Newton's work including chapters on: early influences (Wallis, Barrow, et al.), the binomial theorem, the method of fluxions, the *De Quadratura*, the solid of least resistance and the curve of quickest descent, interpolations and finite differences, the *Arithmetica Universalis*, cubic curves, and the geometry in the *Principia*.

2818. Turnbull, H. W. *James Gregory Tercentenary Memorial Volume*. Edinburgh: Royal Society of Edinburgh, 1939.

See item 2139.

2819. Ullrich, Peter. "Weierstrass' Vorlesung zur 'Einleitung in die Theorie der analytischen Funktionen'". *Archive for History of Exact Sciences* 40 No. 2 (1989), 143-172.

A reconstruction and analysis of several versions of Weierstrass's famous lecture course on the foundations of analytic functions in Berlin between 1861/62 and 1884/85.

2820. Volkert, Klaus. *Geschichte der Analysis.* Mannheim etc.: B. I.Wissenschaftsverlag, 1988.

This book deals with aspects of the history of analysis from classical antiquity to the end of the nineteenth century. It contains a valuable list of references and puts much emphasis of the precursors of Newton and Leibniz, such as Cavalieri, Torricelli, Roverval etc.

2821. Voss, A. "Differential- und Integralrechnung". *Encyklopädie der mathematischen Wissenschaften, II (A2).* Leipzig: B. G. Teubner, 1899, 54–134.

Useful for its extensive references to research of the 18th and 19th centuries. Applications receive more attention than pure theory; contains an illustrated appendix on planimeters and integrators.

2822. Walker, E. *A Study of the Traité des indivisibles of Gilles Personne de Roberval.* New York: Columbia University Press, 1932.

See item 2202.

2823. Weierstrass, Karl. *Introduction into the Theory of (Analytic) Functions.* Münster: Mathematisches Institut, 1986; Braunschweig and Wiesbaden: Vieweg, 1988; Leipzig: Teubner, 1988.

Three different versions of Weierstrass's famous lecture course on the foundations of analytic functions in Berlin. The Münster edition, which follows notes by W. Killing (1868), is largely uncommented. The Braunschweig edition is based on notes by A. Hurwitz (1878) and is commented on by P Ullrich. The Leipzig edition stems from an unknown listener in 1886, includes Weierstrass's elaborations on real functions and is commented on by R. Siegmund-Schultze.

2824. Westfall, Richard S. *Never at Rest. A Biography of Isaac Newton.* Cambridge: Cambridge University Press, 1980, xviii + 908 pp.

Westfall's monumental biography is especially strong on Newton's mathematics, as he has made extensive use of Whiteside's recent work. Chapter 4 deals with Newton's early mathematical discoveries. The scientific work of 1665–1666 is the subject of Chapter 5, whereas Chapter 6 discusses his work while Lucasian professor at Cambridge. Chapter 10 examines the mathematics of the *Principia*, and Chapter 14 the priority dispute with Leibniz.

2825. Whiteside, D. T. "Patterns of Mathematical Thought in the Later Seventeenth Century". *Archive for History of Exact Sciences* 1 (1960/1962), 179–388.

See item 2073.

2826. Woodhouse, R. *A History of the Calculus of Variations in the Eighteenth Century.* New York: Chelsea, 1964, reprint of the 1810 edition.

See item 2229.

2827. Yavetz, Ido. *From Obscurity to Enigma: The Work of Oliver Heaviside 1872-1889.* Vol. 16. (Science Networks: Historical Studies.) Basel etc.: Birkhäuser, 1995.

Examines the first part of Heaviside's career with emphasis on the modern treatment of the problems of electromagnetism rather than giving a close reading of Heaviside's texts.

2828. Young, William Henry. "The Progress of Mathematical Analysis in the Twentieth Century". *Proceedings of the London Mathematical Society* 24 (2) (1926), 421-434.

Deserves attention as a report, mostly on measure and summability, by a mathematician who was involved in the development by virtue of his integral which is equivalent to the Lebesgue integral.

2829. Youschkevitch, Adolf P. "The Concept of Function up to the Middle of the Nineteenth Century". *Archive for History of Exact Sciences* 16 (1977), 37–85.

This analysis of the development of the concept of function up to the general definitions set forth by Hankel and Dirichlet provides a prominent place to 18th-century extensions and revisions of the concept. It shows that Euler's definition of 1755—based merely on the idea of a correspondence—almost coincides with the final 19th-century definitions.

2830. Youschkevitch, Adolf P. "Lazare Carnot and the Competition of the Berlin Academy in 1786 on the Mathematical Theory of the Infinite". In *Lazare Carnot Savant.* Edited by C. C. Gillispie. Princeton: Princeton University Press, 1971.

See item 2242.

2831. Youschkevitch, Adolf P. "Euler und Lagrange ueber die Grundlagen der Analysis". *Sammelband der zu Ehren des 200 Geburtstages Leonhard Eulers.* Berlin: Deutschen Akademie der Wissenschaften zu Berlin, 1959, 224–244.

Argues that Euler's contributions to the foundations of the calculus have been effective and influential, although he had not taken up the basic view of differentials as actual zeros. Suggests that Lagrange's attempt to found the calculus on power series derives from Euler's results.

2832. Youschkevitch, Adolf P. *Die Entwicklung des Funktionsbegriff.* Translated by K. Reich. Munich: Deutsches Museum, 1972.

A 31-page translation of the original Russian.

2833. Youschkevitch, Adolf P. "J. A. da Cunha et les fondements de l'analyse infinitésimale". *Revue d'histoire des sciences et de leurs applications* 26 (1973), 3–22.

J. A. da Cunha (1744–1787) was a Portuguese mathematician whose book, *Principrios Mathematicos* (published posthumously in 1790, translated into French in 1811), is an early attempt to base the calculus on rigorous foundations before either Bolzano or Cauchy. He anticipated the latter in developing a criterion for sequential convergence and in defining the differential of a function.

2834. Zdravkovska, Smilka, and Peter Duren, eds. *Golden Years of Moscow Mathematics*. Vol. 6. (History of Mathematics.) Providence, R.I. and London: American Mathematical Society and London Mathematical Society, 1993.

Gives among other things information about the famous Moscow school of function theory around D. F. Yegorov and N. N. Luzin.

COMPUTING

This bibliography concentrates on the period from Babbage to the invention of the stored program electronic digital computer in the mid-1940s, but also contains items relating to earlier work on mechanical calculation and sequence control mechanisms, as well as items relating to more recent work on programming and artificial intelligence. Works have been emphasized here that deal specifically with issues relevant to the history of mathematics and its connections with the history of computing and computers.

2835. Aiken, H. H., and the staff of the Computation Laboratory. *A Manual of Operation for the Automatic Sequence Controlled Calculator*. Annals of the Computation Laboratory of Harvard University, 1. Cambridge, Mass.: Harvard University Press, 1946, 561 pp.

The first chapter, "Historical Introduction", is a very useful account of the development of calculating machines, difference engines, and Babbage's work. It includes mention of Müller and Torres y Quevedo.

2836. Apokin, I. A., and L. E. Maĭ strov. *Razvitie Vychislitel′nykh Mashin*. Moscow: Nauka, 1974. 400 pp.

An account of the history of digital computing from the earliest aids to calculation to the modern computer. Chapter 1 includes discussion of the abacus in China, Europe, and Russia, while Chapter 2, on mechanical calculators, discusses the work of Jakobson, Chebyshev, and Odhner, as well as Schickard, Pascal, and Leibniz. Chapter 3 covers tabulating machines and electromechanical desk calculators. The next chapter, "The Birth of Electronic Computing," which names M. A. Bonch-Bruevich as having invented an electronic trigger circuit in 1918, one year before the independent work of Eccles and Jordan, describes such projects as the Harvard Mark I, the Atanasoff-Berry Computer, ENIAC, EDVAC, etc. Chapter 5 describes early stored program computers, and states that the first Russian computers were the MESM and BESM. The final four chapters discuss transistorized and integrated circuit computers, computer applications, and the future of computer technology. A large number of references are listed, to both Russian- and English-language sources.

2837. Aspray, William *John von Neumann and the Origins of Modern Computing*. Cambridge, MA: MIT Press, 1990, xviii + 376 pp. tp[]

A lavishly detailed study of its subject.

2838. Aspray, William. "The Mathematical Reception of the Modern Computer: John von Neumann and the Institute for Advanced Study Computer". In Esther R. Phillips, ed. *Studies in the History of Mathematics* Washington: Mathematical Association of America, 1987, 166–194.

2839. Babbage, Charles. *The Ninth Bridgewater Treatise: A Fragment.* London: John Murray, 1837.

Makes numerous references to his work on calculating engines, and includes a short appendix describing the history of his efforts to produce first a difference and then an analytical engine.

2840. Babbage, Charles. *Passages from the Life of a Philosopher.* London: Longman, Green, Longman, Roberts and Green, 1864, 496 pp. Reprinted New York: Augustus M. Kelley, 1969.

Contains several chapters relating to the difference engines and the analytical engine (which have been reprinted in H. P. Babbage [item 2841] and Morrison and Morrison [item 2873]. A fascinating book, which throws much light on the strange character of Charles Babbage.

2841. Babbage, H. P., ed. *Babbage's Calculating Engines: Being a Collection of Papers Relating to Them, Their History, and Construction.* London: E. and F. N. Spon, 1889, 342 pp. Reprinted Los Angeles: Tomash Publishers, 1983.

A reprinting of the writings of Babbage and others, on both the difference and the analytical engines, edited by his son. Much of the material has been reprinted in Morrison and Morrison (item 2873).

2842. Bauer, F. L. *Between Zuse and Rutishauser—The Early Development of Digital Computing in Central Europe.* Item 2871, pp. 505–524.

A very interesting and well-illustrated paper, covering both computer hardware and programming languages and techniques. The relationship between Zuse's work on computers and his ideas for the Plankalkül is explored, and the influence of his work on such people as Rutishauser is discussed.

2843. Bauer, F. L., and H. Wössner. "The 'Plankalkül' of Konrad Zuse: A Forerunner of Today's Programming Languages". *Communications of the Association for Computing Machinery* 15 (7) (1972), 678–685.

A fairly detailed account of the language, and an analysis of it compared to modern programming languages.

2844. Bobrow, Daniel G. "Artificial Intelligence in Perspective: A Retrospective on Fifty Volumes of the Artificial Intelligence Journal". *Artificial Intelligence* 59 no. 1–2 (1993), 5–20.

This paper gives a picture of the state of artificial intelligence as reflected in the journal of that name.

2845. Bowden, B. V., ed. *Faster Than Thought.* London: Sir Isaac Pitman and Sons, 1953, 416 pp.

Contains much material on Babbage, including a reprint of the Lady Lovelace translation of Ménabréa's article. The major part of the book consists of chapters on the then-current British computing machine projects.

2846. Burks, A. W., H. H. Goldstine, and J. von Neumann. *Preliminary Discussion of the Logical Design of an Electronic Computing Instrument. Vol. 1, Part 1.* Princeton: Institute for Advanced Study, 28 June 1946; 2nd ed. 2 September 1947. Reprinted in item 2883; extracts reprinted in Randell, item 2876.

The famous report, on the design of what is now known as the "von Neumann"–style machine. Gives a detailed description of the plans for the parallel binary I.A.S. computer, including great detail on the arithmetic unit.

2847. Collier, B. "The Little Machines that Could've: The Calculating Machines of Charles Babbage". Dissertation, Harvard University, 1970.

A valuable detailed study of Babbage's machines, and of the circumstances surrounding their development. Based on the Babbage correspondence in the British Museum, the Babbage sketchbooks and drawings in the Science Museum, and the Buxton collection of Babbage manuscripts in the Museum of the History of Science at Oxford.

2848. Comrie, L. J. "The Application of the Hollerith Tabulating Machine to Brown's Tables of the Moon". *Monthly Notices, Royal Astronomical Society,* 92 (7) (1932), 694–707.

Describes the facilities and operation of then current punches, tabulators, and sorters, and the use of these for calculating E. W. Brown's Tables of the Moon. States that Hollerith equipment was first used at the Nautical Almanac Office in 1929.

2849. Comrie, L. J. "Modern Babbage Machines". *Bulletin, Office Machinery Users Assoc. Ltd. (London)* (1932), 29 pp.

An article on difference engines and techniques.

2850. Comrie, L. J. "The Application of Commercial Calculating Machines to Scientific Computing". *Mathematical Tables and Other Aids to Computation* 2 (1946), 149–159.

Extended survey of the use of desk calculators, adding machines, and punched card machinery for scientific calculations.

2851. Comrie, L. J. "Babbage's Dream Come True". *Nature* 158 (1946), 567–568.

Review of Aiken, item 2835.

2852. Cortada, James W. *The Computer in the United States: From Laboratory to Market, 1930–1960.* Armonk, N.Y.: M. E. Sharpe, 1993, xx + 183 pp.

As the title indicates, this book concentrates on the all-important commercial aspects of computers, without which no computers would have been built at all.

2853. Davis, Martin. "Mathematical Logic and the Origin of Modern Computers". In Esther R. Phillips, ed. *Studies in the History of Mathematics.* Washington: Mathematical Association of America, 1987, 137–165.

A study of the work of Alan Turing.

2854. Eckert, J. P. "A Preview of a Digital Computing Machine". *Theory and Techniques for the Design of Electronic Digital Computers. Lectures delivered 8 July–31 Aug. 1946.* Edited by C. C. Chambers. Philadelphia: Moore School of Electrical Engineering, Univ. of Pennsylvania, 1947, 10.1–10.26.

An account of the plans for EDVAC, and a description of its intended order code. Discusses how the decision to provide a single common memory for constants, variables, and instructions led to the concept of a stored program, and the implications of this concept on computer design.

2855. Fleck, G., ed. *A Computer Perspective ("By the Office of Charles and Ray Eames").* Cambridge, Mass.: Harvard University Press, 1973, 175 pp.

A profusely illustrated book based on an I.B.M.-sponsored exhibition. Although aimed at a popular audience, it contains a vast amount of information, relating directly or indirectly to the origins of computers, that is not readily available.

2856. Goldstine, Herman H. *The Computer from Pascal to von Neumann.* Princeton, N.J.: Princeton University Press, 1972, 378 pp. Reprinted Princeton, N.J.: University Press, 1993.

The first part of this book discusses the history of digital and analogue calculating devices and concurrent developments in mathematics. However, the main purpose of the book is to give an extensive account, from the viewpoint of a particular participant, of the ENIAC, EDVAC, and I.A.S. projects. The account makes available for the first time a wealth of material taken from contemporary documents. Particular attention is paid to the work of von Neumann and to his role in the EDVAC and I.A.S. projects.

2857. Grabiner, Judith V. "Partisans and Critics of a New Science: The Case of Artificial Intelligence and some Historical Parallels". In *History and Philosophy of Modern Mathematics.* (Minnesota Studies in Philosophy of Science, No. 11.) Minneapolis: University of Minnesota Press, 1988. 329–345.

The author uses historical methods to evaluate the development of an important area of twentieth-century mathematical research.

2858. Gravelaar, N. L. W. A. “John Napier’s Werken”. *Verhandelingen der Koninklijke Akademie van Wetenschappen to Amsterdam. Eerste Sectie, Deel VI, No. 6.* Amsterdam: Johannes Müller, 1899, 159 pp. In Dutch.

The fullest analysis available of John Napier’s work on logarithms, calculating aids, arithmetic, algebra, etc. Almost the only publication to point out that Napier’s “Local Arithmetic” (Appendix to his *Rabdologiae*, 1617; see item 2874 below) was nothing other than arithmetic in binary notation.

2859. Hawkins, W. F. “The First Calculating Machine (John Napier, 1617)”, *The New Zealand Mathematical Society Newsletter* 16 (December 1979), Supplement, 1–23.

Complete translation (with commentary) of John Napier’s specification of his Promptuary for multiplication (in *Rabdologiae*, 1617; see item 2874 below), which was a major advance from abacus-type devices towards fully mechanical calculating machines. A working Promptuary has been constructed from this translation.

2860. Hinsley, F. H., with E. E. Thomas, C. F. G. Ransom, and R. C. Knight. *British Intelligence in the Second World War: Its Influence on Strategy and Operations. Vol. 1.* London: H.M.S.O., 1979, 601 pp.

The first official account of this subject, written with unrestricted access to wartime files, including files which are unlikely ever to be made public. This first of three volumes covers the period until the summer of 1941. Contains much authoritative information regarding the extent to which the various types of Enigma messages were deciphered, but little on the techniques used or the individuals concerned. Appendix 1 (pp. 487–495), entitled “Breaking the Enigma: Polish, French and British Contributions,” indicates that the Polish cryptanalysts produced their first “cryptographic Bombe” in 1937, and that the first of the British Bombes, “which were of quite different design from the Polish, and much more powerful,” was delivered by May 1940.

2861. Hodges, Andrew. *Alan Turing: The Enigma.* New York: Simon & Schuster, 1983. x + 588 pp. The second edition, London: Vintage, Random House, 1992, contains some new documents.

A personal and scientific biography by a mathematician whose account was the basis for a very successful stage play. Recounts Turing’s pioneering work in the 1930s on computability, his war-time contributions to the deciphering of the Enigma code and his part in the postwar development of the modern computer. The book has been translated into German, French, and Italian. The author maintains a substantial web site devoted to Turing at The Alan Turing Home Page (http://www.turing.org.uk/turing/)

2862. Horsburgh, E. M., ed. *Napier Tercentenary Celebration: Handbook of the Exhibition*. Edinburgh: Royal Society of Edinburgh, 1914.Also published as *Modern Instruments and Methods of Calculation: A Handbook of the Napier Tercentenary Celebration Exhibition*. London: G. Bell and Sons, 1914. Reprinted Los Angeles: Tomash Publishers, 1983.

Contains, in addition to Percy Ludgate's article on "Automatic Calculating Machines," good descriptions of various then current calculating instruments and machines: Archimedes, Colt's Calculator, Brunsviga, Burroughs Adding and Listing machine, Comptometer, Layton's Arithmometer, Mercedes-Euklid Arithmometer, Millionaire, and the Thomas Arithmometer.

2863. Hu, Shih-Hua. "Mathematics in the Age of Information Processing". In Chinese. *Advances in Mathematics* [Beijing] 17 (1) (1988), 12–20.

This article consists of philosophical reflections on the vital question of the relation of mathematics and human thought in general to computers.

2864. Johnson, Jeffrey. "An Introduction to the Mathematical Revolution Inspired by Computing". In *The Mathematical Revolution Inspired by Computing*. (Institute for Mathematics and its Applications Conference Series, New Series, No. 30.) New York: Oxford University Press, 1991. 3–18.

A general survey intended as introduction to the more technical articles in the volume.

2865. Kepler, Johannes. *Opera omnia. Vol. 7.* Edited by Ch. Frisch. Frankfurt: Heyder & Zimmer, 1858.

Wilhelm Schickard's first report of his calculating machine is quoted briefly on p. 300 (cf. Kepler, 1718, p. 683, item 2867.).

2866. Kepler, Johannes. *Gesammelte Werke. Vol. 18.* Edited by Max Caspar. Munich: C. H. Beck, 1959.

Prints letters from Wilhelm Schickard to Kepler of 20 December 1623 and 25 February 1624, describing his calculating machine. See also item 2154.

2867. Kepler, Johannes. *Epistolae ad Joannem Kepplerum*. Edited by Michael Gottlieb Hanschius. Leipzig: n.p., 1718.

Wilhelm Schickard's letter to Kepler of 20 December 1623, in which he described very briefly his calculating machine, is printed on p. 683. That account was cited by D. Stewart and W. Minto (1787, item 2878, p. 39), and by C. Frisch (Kepler, 1858, item 2865, p. 300).

2868. Lavington, S. *Early British Computers*. Manchester: Manchester University Press, 1980, 139 pp.

Computing in Great Britain, from the 1930s to 1960. Brief illustrated accounts of COLOSSUS, ACE, EDSAC, Manchester Mark 1, DEUCE, PEGASUS, etc.

2869. Lovelace, Augusta Ada, Countess of. "Sketch of the Analytical Engine Invented by Charles Babbage, by L. F. Ménabréa of Turin, Officer of the Military Engineers, with Notes upon the Memoir by the Translator". *Taylor's Scientific Memoirs* 3 (1843) Article 29, 666–731. Reprinted in Bowden, item 2845 above, Morrison and Morrison, item 2873 below, and H. P. Babbage, item 2841 above.

The single most important paper published on Babbage's analytical engine. Lady Lovelace's notes are more lengthy than the original Ménebréa paper, which is itself a good description of the basic principles of the analytical engine.

2870. Lyndon, R. C. "The Zuse Computer". *Mathematical Tables and Other Aids to Computation* 2 (20) (1947), 355–359.

Describes the then incomplete Z4 computer. At this date the memory held 16 numbers—the projected size being 1024.

2871. Metropolis, N., et. al., eds. *A History of Computing in the Twentieth Century*. New York: Academic Press, 1980.

The proceedings of a conference at Los Alamos in 1978, at which most of the pioneers of computing presented their accounts of early computing. A major source for the history of computing.

2872. Moore, D. L. *Ada, Countess of Lovelace: Byron's Legitimate Daughter*. London: John Murray, 1977, 397 pp.

A carefully researched biography, which provides a very good account of the remarkable yet tragic life of Lady Lovelace. Her friendship and collaboration with Charles Babbage are covered at some length, though there is comparatively little technical detail concerning their correspondence and discussions about the analytical engine.

2873. Morrison, P., and E. Morrison, eds. *Charles Babbage and his Calculating Engines: Selected Writings by Charles Babbage and Others*. New York: Dover Publications, 1961, 400 pp.

A valuable selection of material on Babbage's engines, taken mainly from *Passages from the Life of a Philosopher* (item 2840) and from *Babbage's Calculating Engines* (item 2841).

2874. Napier, John. *Rabdologiae*. Edinburgh: Andreas Hart, 1617, 154 pp. In Latin. Later editions: Leyden 1626, 1628; Italian translation

Rabdologia, Verona, 1623; Dutch translation *Eerste Deel Vande Nievwe Telkonst*, Gouda, 1626. Facsimile edition Osnabruch: O. Zeller, 1966.

John Napier described his numbering rods ("Napier's Bones") for multiplication and division, with special rods for square and cube roots and with applications to mensuration. The appendix on Local Arithmetic was the first full publication of binary arithmetic, as far as square root extraction. Napier stressed that the most important part of the book is the Appendix on the Promptuary for multiplication, which can be regarded as the first calculating machine (cf. W. F. Hawkins, 1979, item 2859).

2875. Nijholt, Anton. "From Mechanical to Theoretical—Aspects of the Origins of Theoretical Computer Science". (CWI Tract, No. 42.) Amsterdam: Centrum voor Wiskunde en Informatika, 1987. 9–42.

The aspects referred to in the title are the generative grammars of Noam Chomsky and other parts of formal language theory.

2876. Randell, B. *The Origins of Digital Computers: Selected Papers*. 3rd ed. Berlin: Springer Verlag, 1982, 580 pp.

A set of 34 original papers and manuscripts relating to the origins of digital computers. Introductory and linking text is provided in order to place the work of the various pioneers into perspective, and to cover such topics as early calculating machines and sequence-control mechanisms and the development of electromagnetic and electronic digital calculating devices. There is a valuable annotated bibliography of over 850 items.

2877. Sammet, Jean E. "Symbolic Computation: the Early Days (1950–1971)." In *Computers in Mathematics*. Stanford, CA, 1986, 1990.

A survey of some of the highlights from the early days of symbolic computation.

2878. Stewart, D. (Earl of Buchan), and W. Minto. *An Account of the Life, Writings and Inventions of John Napier, of Merchiston*. Perth: R. Morison, 1787, 142 pp.

A valuable book about Napier, with clear accounts of the computing devices in *Rabdologiae* (Napier, 1617, item 2874). A brief historical survey of calculating machines after the Promptuary begins (p. 39) with Schickard's first report of his calculating machine, in his 1623 letter to Kepler (cf. Kepler, 1718, item 2867, p. 683).

2879. Sugiyama, Hiroshi. "Principle of Dynamic Programming as a Natural Law Discovered by Richard Bellman". *Journal of Mathematical Analysis and its Applications* 119 (1–2) (1986), 55–71.

The story of the invention of dynamic programming by Richard Bellman while working on defense-related projects.

2880. Travis, I. "The History of Computing Devices". *Theory and Techniques for the Design of Electronic Digital Computers. Lectures Delivered 8 July–31 Aug. 1946.* Edited by C. C. Chambers. Philadelphia, Pa.: Moore School of Electrical Engineering, University of Pennsylvania, 1947, 2.1–2.3.

A very brief account of calculating techniques, and of the development of analogue and digital calculating devices.

2881. Turing, Alan M. "On Computable Numbers, with an Application to the Entscheidungsproblem". *Proceedings of the London Mathematical Society* 42 (1936), 230–267.

The famous paper which introduced the concept of a "universal" computing machine. See also A. M. Turing, "Correction to 'On Computable Numbers'", *Proceedings of the London Mathematical Society* 43 (1937), 544–548.

2882. Turing, Alan M. *Proposals for Development in the Mathematics Division of an Automatic Computing Engine (A.C.E.). Report E.882.* Teddington, Middlesex, England: Executive Committee, National Physical Laboratory, 1945. Reprinted as *NPL Report, Computer Science 57*, April 1972.

A report, which also carried the title †Proposed Electronic Calculator†, giving detailed plans for the ACE, known to have been written some time during 1945.

2883. Von Neumann, J. *Collected Works.* Edited by A. H. Taub. Oxford: Pergamon, 1963. 6 vols.

Includes the very important papers on computers, written jointly with A. W. Burks and H. H. Goldstine (1946, item 2846), and with H. H. Goldstine in 1947 and 1948.

2884. Wilkes, M. V. *Automatic Digital Calculators.* London: Methuen, 1956, 305 pp.

Contains one of the best early surveys and detailed discussions of the origins of computers. After a detailed discussion of the Babbage analytical engine, Ludgate is mentioned, and Torres y Quevedo's work is described very briefly. It then gives quite a lot of detail on the Harvard Mark I, ENIAC, EDVAC, the Bell Laboratories Computer Models V and VI, and the Harvard Mark II. (The early part of the book is based on the Cantor Lectures given by Wilkes in 1951.)

2885. Wilkinson, J. H. "The Pilot ACE at the National Physical Laboratory". *Radio and Electronics Engineer* 45 (7) (July 1975), 336–340.

Provides a detailed account of the trials and tribulations involved in developing the Pilot ACE Computer, whose first successful public demonstration was in December 1950. It describes how the design was

based on that of the "Test Assembly," a prototype design by a team led by Harry Huskey, which was in turn based on what Turing described as Version V of his original 1945 proposal for an Automatic Computing Engine. It states that the term "Engine" was chosen "in recognition of the pioneering work of Babbage on his Analytical Engine," and that Turing was already at work on Version V in May 1946 when the author joined N.P.L.

2886. Zuse, K. *Der Computer—Mein Lebenswerk*. Munich: Verlag Moderne Industrie, 1970.

An autobiography, with many technical details about his work, starting in 1934, on the design of program-controlled calculators. The work of his collaborator Schreyer, who investigated the design of an electronic version of the Z3, and of Dirks, who developed a magnetic drum store, is also covered.

DIFFERENTIAL EQUATIONS

2887. Bemelmans, Josef; Stefan Hildebrandt; Wolf von Wahl. "Partielle Differentialgleichungen und Variationsrechnung. In *Ein Jahrhundert Mathematik 1890–1990*, (Braunschweig: Vieweg, 1990), 149–230. "

There are four parts, an introduction, concerned with the pre-1890s situation in the calculus of variations (PDE of first-order, the Weierstrass theory, Pfaffian systems, Jacobi's method and Lie's method, etc.), a second part concerned with the foundations (pre-1945) of the modern theory, a third concerned with the after-1945 theory, and a fourth, which treats the regularity theory for the nonstationary Navier-Stokes equation as a unifying example. Nineteen thumbnail biographies with photos and a bibliography of 256 items. Reviewed by J. S. Joel in **MR** 92e:01050.

2888. Burkhardt, Heinrich F. K. L. "Entwicklungen nach oscillirenden Functionen und Integration der Differentialgleichungen der mathematischen Physik". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 10 (1901–1908), viii + 1804 pp. Also issued separately in 2 vols. Leipzig: B. G. Teubner, 1908, xii + xii + 1800 pp.Reprinted New York: Johnson Reprint Corp., 1960.

Discusses in great detail differential equations originating in mathematical physics, with special emphasis on expansion methods for their solution. Covers almost all ramifications of this huge subject from its beginning in the 18th century through the end of the 19th century, and is extremely helpful as a guide to primary sources. See also item 3221.

2889. Demidov, Sergei S. "K istorii teorii differentsialnykh uravnenii s chastnymi proizvodnymi". *Istoriko-Matematicheskie Issledovaniia* 18 (1973), 181–202.

Considers the attempts to reduce second order partial differential equations to simple standard forms from Euler (1770) to du Bois-Reymond (1889), and the changing programs toward a general theory of such equations.

2890. Demidov, Sergei S. "Differentsialnye uravneniya s chastnymi proizvodnymi v rabotakh zh. dalambera". *Istoriko-Matematicheskie Issledovaniia* 19 (1974), 94–124.

Provides a comprehensive and detailed survey of d'Alembert's contributions to the theory of partial differential equations, consisting of the coefficient method, separation of variables, and expansion in trigonometric series. Argues that d'Alembert revived Euler's interest in the subject.

2891. Demidov, Sergei S. "Vozniknovenie teorii differentsialnykh uravnenii s chastnymi proizvodnymi". *Istoriko-Matematicheskie Issledovaniia* 20 (1975), 204–220.

Identifies five early occurrences of partial differential equations in the work of Euler (1734, 1760s) and d'Alembert (1743, 1747, 1749), which together constitute the early history of the theory of these equations. Provides a thorough analysis of the partial differential equations which occur in Euler's geometric work of 1734.

2892. Demidov, Sergei S. "The Study of Partial Differential Equations of the First Order in the 18th and 19th Centuries." *Arch. Hist. Exact Sci.* 26 (1982), no. 4, 325–350.

Surveys the history of first order partial differential equations in the 18th and 19th centuries. Distinguishes four periods in the development of this theory: a formal-analytical period up to 1770 (Euler, d'Alembert), a geometrical period (Lagrange, Monge), the period of C. G. Jacobi's second method, and the period of Lie's general theory. This is a revised version of the author's "Razvitie issledovanii po uravnenijam s chastnymi proizvodnymi pervogo porjadka v XVIII–XIV vv". *Istoriko-Matematicheskie Issledovaniia* 25 (1980), 71–103.

2893. Demidov, Sergei S. "On the History of the Theory of Linear Differential Equations." *Arch. Hist. Exact Sci.* 28 (1983), no. 4, 369–387.

On the analogy between algebraic equations and linear differential equations as seen in the works of Lagrange, d'Alembert, Libri, and Liouville.

2894. Dobrovolski, W. A. "Sur l'histoire de la classification des points singuliers des équations différentielles". *Revue d'Histoire des Sciences* 25 (1972), 3–11.

Surveys 19th-century studies about singular points of differential equations and analytical functions. Contends that the classification theory of singularities originates in the work of N. E. Joukovsky (1876).

2895. Dobrovolski, W. A. "Contribution à l'histoire du théorème fondamental des équations différentielles". *Archives Internationales d'Histoire des Sciences* 22 (1969), 223–234.

Traces the origins and principal methods for the proof of existence and uniqueness of solutions to differential equations in the work of Cauchy and Weierstrass.

2896. *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* Leipzig: B. G. Teubner (issued in three parts), 1899–1916.

The *Encyklopädie* was set up as a compendium of the state of knowledge around 1900. The articles are very detailed and cover narrow subdisciplines. They are a useful guide to the primary literature and frequently contain historical remarks or judgments. Volume II.1.1. contains items 2898, 2900, 2901, 2902, 2903, 2904, and 2905, which are relevant to the theory of differential equations. See also items 5, 2283.

2897. Engelsman, Steven B. "Lagrange's Early Contributions to the Theory of First Order Partial Differential Equations". *Historia Mathematica* 7 (1980), 7–23.

Argues that both Lagrange's theory of singular solutions to ordinary differential equations and his revision of the concept of solution to partial differential equations in the 1770s originated in the idea that the entire set of solutions of a differential equation can be found by means of variation of constants from a solution containing an adequate number of constants.

2898. Painlevé, P. "Gewöhnliche Differentialgleichungen; Existenz der Lösungen", article nr. II (A4a) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 189–229.

2899. Simonov, N. I. "Sur les recherches d'Euler dans le domaine des équations différentielles". *Revue d'Histoire de Sciences* 21 (1968), 131–156.

Provides a brief survey of Euler's achievements in the theory of ordinary and partial differential equations. Deals with these matters from a strictly mathematical point of view.

2900. Vessiot, E. "Gewöhnliche Differentialgleichungen; Elementare Integrationsmethoden", article nr. II (A4b) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 230-293.

2901. Weber, E. von. "Partielle Differentialgleichungen", article nr. II (A5) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 294–399.

2902. Maurer, L., and H. Burkhardt. "Kontinuierliche Transformationsgruppen". article nr. II (A6) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 401–436.

This article focuses almost exclusively on the ideas of S. Lie.

2903. Bôcher, Maxime. "Randwertaufgaben bei gewöhnlichen Differentialgleichungen", article nr. II (A7a) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 437–463.

2904. Burkhardt, Heinrich, and W. F. Meyer. "Potentialtheorie (Theorie der Laplace-Poisson'schen Differentialgleichung)", article nr. II (A7b) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 464–503.

See also item 3647.

2905. Sommerfeld, A. "Randwertaufgaben in der Theorie der partiellen Differentialgleichungen", article nr. II (A7c) in *Encyklopädie der mathematischen Wissenschaften.* Vol. II.1.1. *Analysis.* 504–570.

2906. Engelsman, Steven B. "Lagrange's Early Contributions to the Theory of First Order Partial Differential Equations". *Historia Mathematica* 7 (1980), 7–23.

Considers Lagrange's reformulation, in 1776, of Euler's definition of a complete solution of a first order differential equation, derived from an earlier approach using the method of "variation of constants."

2907. Gilain, Christian. "La théorie géométrique des équations différentielles de Poincaré et l'histoire de l'analyse". Dissertation, Université de Paris I, 1977, 145 pp.

Characterizes Poincaré's article "Sur les courbes définies par une équation différentielle" (1880–1886) as a turning point in the study of differential equations, because it breaks with the dominance of complex-function methods, initiates a global study of differential equations, and introduces topology as a method of research.

2908. Hofmann, Joseph E. "Über Auftauchen und Behandlung von Differentialgleichungen im 17. Jahrhundert". *Humanismus und Technik* 15 (Part 3), (1972), 1–40.

Argues that Debeaune's differential equation (1638) finally inspired Leibniz's formal treatment of linear first order differential equations and Johann Bernoulli's method of solving differential equations by power series and variation of constants. See also item 2084.

2909. Lützen, Jesper. "Heaviside's Operational Calculus and the Attempts to Rigorise It". *Archive for History of Exact Sciences* 21 (1979/1980), 161–200.

Argues that there were two approaches to make Heaviside's operational calculus rigorous: one based on integral transformations and the other leading to abstract algebraical formulation. See also item 2977.

2910. Lützen, Jesper. "The Prehistory of the Theory of Distributions". Dissertation, University of Aarhus, Denmark, November 1979, vii + 389 pp. Also published in the series Studies in the History of Mathematics and Physical Sciences, 7. New York: Springer, 1982.

Distinguishes four independent fields which inspired the theory of distributions: generalized solutions to differential equations, generalized Fourier transforms, generalized functions, and de Rham-currents. Argues that Schwartz's desire for unification and his understanding of duality were instrumental for the birth of distribution theory.

2911. McHugh, J. A. M. "An Historical Survey of Ordinary Linear Differential Equations with a Large Parameter and Turning Points". *Archive for History of Exact Sciences* 7 (1970/1971), 277–324.

This is a highly technical survey article, describing mathematical techniques and main results of this theory between 1830 and 1970.

Extensive bibliography of primary sources.

2912. Nirenberg, Louis. “Partial Differential Equations in the First Half of the Century”. In *Development of Mathematics 1900–1950, (Luxembourg, 1992)*, 479–515, (Basel: Birkhäuser, 1994.

An account by one of the main contributors. Reviewed by Jesper Lützen in **MR** 95j:35003.

2913. Ravetz, Jerome R. “Vibrating Strings and Arbitrary Functions”. In *The Logic of Personal Knowledge: Essays Presented to M. Polanyi on his 70th Birthday.* London: Routledge and Kegan Paul, 1961, 71–88.

Deals with the famous controversy concerning the vibrating string, and describes different standpoints in terms of the relation which the abstract mathematical theory was considered to have with the experimental phenomena: should it explain all (D. Bernoulli), some (L. Euler, J. L. Lagrange), or none (J. d’Alembert) of the phenomena. Pursues the issue of arbitrary functions and trigonometric series through the work of Fourier of 1807.

2914. Rothenberg, Siegfried. *Geschichtliche Darstellung der Entwicklung der Theorie der singulären Lösungen totaler Differentialgleichungen von der ersten Ordnung mit zwei variablen Grössen.* Dissertation, University of Munich; Leipzig: Teubner, 1908.

Divides the history of singular solutions into seven periods, and argues that a paradox in Lagrange’s theory was the prime motivation for 19th-century attempts to understand the nature of such solutions.

2915. Schlissel, Arthur. “The Development of Asymptotic Solutions of Linear Ordinary Differential Equations, 1817–1920”. *Archive for History of Exact Sciences* 16 (1976/1977), 307–378.

Describes the development through generalization and ramification of the notion of asymptotic solutions from Carlini (1817) to Debye’s “saddle point method.” See also items 2791, 3239.

2916. Schlesinger, L. *Handbuch der Theorie der Linearen Differentialgleichungen.* Leipzig: B. G. Teubner, 1895–1898. New York, N.Y.: Johnson Reprint, 1968. 2 vols. in 3.

Covers the same material as 2917 in more mathematical detail, particularly on the work of Gauss, Fuchs, and Poincaré.

2917. Schlesinger, L. “Bericht über die Entwickelung der Theorie der Linearen Differentialgleichungen seit 1865”. *Jahresbericht der Deutschen Mathematiker-Vereinigung* 18 (1909), 133–266.

Strictly a report, not a history, but contains a remarkable number of references to original papers; this item has a bibliography of 1,742 items, listed chronologically, analyzed under 10 headings, indexed by author, and preceded by a pertinent discussion of the main lines of mathematical development. See 2916 for a more detailed treatment by the same author.

2918. Schlissel, Arthur. “The Initial Development of the WKB Solutions of Linear Second Order Ordinary Differential Equations and Their Use in the Connection Problem”. *Historia Mathematica* 4 (1977), 183–204.

Traces the idea of WKB solution back to the work of George Green (1837) and analyzes the attempts to rigorize it. Approximate solutions and asymptotic solutions to equations with non-analytic coefficients, with particular reference to the connection problem, as presented by Gans, Jeffreys, Kramers, and others in the 1920s.

2919. Simonov, N. I. “Sur les recherches d’Euler dans le domaine des équations différentielles”. *Revue d’histoire des sciences et de leurs applications* 21 (1968), 131–156.

See item 2899.

2920. Truesdell, Clifford A. *The Rational Mechanics of Flexible or Elastic Bodies 1638–1788*. (Leonhardi Euleri Opera omnia series 2 volumen XI/2.) Zurich: Orell Füssli, 1960, 435 pp.

“Editor’s Introduction” to volumes 12 and 13 of Euler’s *Opera omnia*, Series 2. See also item 3260.

2921. Wallner, C. R. “Totale und partielle Differentialgleichungen; Differenzen und Summenrechnung; Variationsrechnung”. In *Vorlesungen über Geschichte der Mathematik. Vierter Band; von 1759 bis 1799.* Edited by Moritz Cantor. Leipzig: Teubner, 1908, 871–1074.

This section in the classic by Cantor is still of value as an introduction to the primary literature of ordinary and partial differential equations in the second half of the 18th century.

ELECTRICITY AND MAGNETISM

The sciences of electricity and magnetism have a very long history about which much has been written. What follows is not intended to be a comprehensive bibliography of this literature but for the most part is confined to works dealing with these subjects in their mathematical mode. Studies treating the earlier, non-mathematical stages in their development have in general been omitted, as have those which, though they deal with more recent events, are chiefly concerned with experimental matters or with technological applications. Only in the case of Faraday has an exception been made here: even though Faraday used no mathematics, the importance of his contributions to the rise of electromagnetic field theory was such that two major studies of his work, by Bence Jones, item 2969, in the 19th century, and L. P. Williams, item 3019, in the 20th, have been included. These are, however, only two of many works devoted to one or another aspect of Faraday's electrical and magnetic researches; no attempt has been made to encompass the remainder. Finally, studies dealing with 20th-century developments in relativity and quantum theory have also been omitted. In other words, the intention has been to survey what has been written on the history of the classical mathematical theories of electromagnetism. The list is not restricted, however, to works in which the mathematical content is overt. Rather, the aim has been to provide a reasonably comprehensive coverage (especially of the English-language literature) of works dealing in one way or another with the evolution of electrical and magnetic theory in the period when that theory had become mathematical in form, whether or not those works are themselves expressed in technical mathematical language. A few studies have been included that treat 18th- and early 19th-century steps towards mathematizing the subject, but the majority refer to developments during the heyday of classical physics, the period between 1850 and 1905.

Bibliographies

2922. Ekelöf, Stig, ed. *Catalogue of Books and Papers Relating to the History of Electricity in the Library of the Institute for Theoretical Electricity, Chalmers University of Technology.* Gothenberg: Chalmers University Books, 1964–1966, 109 pp.; 111 pp. 2 vols.

The catalogue of the valuable collection that has been formed over many years by Professor Ekelöf. Vol. I deals with works published prior to 1820, Vol. II with those published after that date. The collection is rich in Continental and especially Scandinavian material. It does not aspire to completeness; the aim has been to assemble "not all works, but all *important* works."

2923. Frost, A. J., ed. *Catalogue of Books and Papers Relating to Electricity, Magnetism, the Electric Telegraph, etc., including the Ronalds Library.* London and New York: E. and F. Spon, 1880, xxvii + 564 pp.

A catalogue initially compiled over many years by the famous telegraph engineer, Sir Francis Ronalds, F.R.S., up to his death in 1873. The catalogue includes not only titles of the works in Ronalds' own remarkable collection of materials on electricity, magnetism, and related subjects, but also all other works on the same subjects which came to his notice. Entries are listed alphabetically by author. The Ronalds collection itself, particularly rich in Continental publications, is now housed at the Institute of Electrical Engineers, London, where it is supplemented by the smaller but also very valuable Silvanus P. Thompson collection.

2924. Mottelay, Paul Fleury. *Bibliographical History of Electricity and Magnetism, Chronologically Arranged....* London: Charles Griffin & Co., 1922, xx + 673 pp.

A monumental work, chronologically arranged, advancing from earliest times up to the age of Faraday. Entries amount to brief accounts of the publications, discoveries, or inventions attributed to the authors noted at each date, to which are appended more or less extensive lists of authorities consulted.

2925. Weaver, William D., ed. *Catalogue of the Wheeler Gift of Books, Pamphlets and Periodicals in the Library of the American Institute of Electrical Engineers.* Introduction, descriptive and critical notes by Brother Potamian. New York: American Institute of Electrical Engineers, 1909, viii + 504 pp.; 475 pp. 2 vols.

An annotated catalogue of the celebrated Latimer Clark collection, of which it was claimed at the time it was sold that it held "practically every known publication in the English language previous to 1886, on magnetism, electricity, galvanism, the lodestone, mariner's compass, etc." A number of other items are included that were published after that date, and many in other languages. The order of entries in the catalogue is chronological, with a separate chronological listing of "Excerpts from Periodicals-Miscellanea." There are an index of authors and an elaborate system of cross-referencing of entries. There is also a separate subject index for the very extensive section of the collection that relates to the telegraph.

2926. Wilson, David B., ed. *Catalogue of the Manuscript Collections of Sir George Gabriel Stokes and Sir William Thomson, Baron Kelvin of Largs, in the Cambridge University Library.* Cambridge: Cambridge University Library, 1976, 589 pp.; 363 pp. 2 vols.

An invaluable guide to two large and important collections of manuscripts.

Historical Monographs and Articles

2927. *Aepinus's Essay on the Theory of Electricity and Magnetism.* Introductory monograph and notes by R. W. Home Translation by P. J. Connor. Princeton, N.J.: Princeton University Press, 1979, xiv + 514 pp.

Includes a full English translation of Aepinus's *Essay* (1759), together with an annotated bibliography of his published writings and a 224-page introductory monograph comprising a biographical outline and an extended discussion of the eighteenth-century sciences of electricity and magnetism and the place of Aepinus's work therein. It is argued that even though Aepinus was not prepared to assume any particular form for the laws of electrical and magnetic action, his work nevertheless constitutes the beginning of the mathematical sciences of electricity and magnetism, and thereby an important step in the mathematization of physics more generally.

2928. Agostino, Salvatore d'. "I vortici dell'etere nella teoria del campo elettromagnetico di Maxwell: La funzione del modello nella construzione della teoria". *Physis* 10 (1968), 188–202.

Discusses the different roles played by mechanical models of the aether in Maxwell's various papers on electrodynamics.

2929. Agostino, Salvatore d'. "Il pensiero scientifico di Maxwell e lo sviluppo della teoria del campo elettromagnetico nella memoria 'On Faraday's Lines of Force'". *Scientia* 103 (1968), 291–301. French translation in supplement, pp. 155–164.

Examines Maxwell's ideas on the nature of physical theories and on methodology, as set out in his first memoir on electromagnetism and elsewhere. Focuses particularly on his advocacy of theoretical pluralism, and on his search for mechanical models for physical theories.

2930. Agostino, Salvo d'. "Hertz's Researches and Their Place in Nineteenth Century Theoretical Physics." *Centaurus* 36 (1993), no. 1, 46–82.

Shows the relationship of Maxwell's work to the structural background of the work of Heinrich Hertz.

2931. Agostino, Salvatore d'. "La scoperta di una velocità quasi uguale alla velocità della luce nell'elettrodinamica di Wilhelm Weber (1804–1891)". *Physis* 18 (1976), 297–318.

Describes how a constant with the dimensions of a velocity appeared in Weber's fundamental law of electrodynamic action, and discusses the implications of the discovery of Weber and Kohlrausch that its value approximated that of the velocity of light. Aruges that Weber did not attach any special significance to this result, and in this connection contrasts Weber's research program, seen as aiming to reduce electrodynamics to mechanics, with Maxwell's program based on contiguous action and the notion of a field.

2932. Archibald, Thomas. "Energy and the Mathematization of Electrodynamics in Germany, 1845–1875." *Arch. Internat. Hist. Sci.* 39 (1989), no. 123, 276–307.

Compares and analyzes the differing views of electrodynamics taken by figures such as W. Weber, C. Neumann, Clausius and Helmholtz.

2933. Berkson, William. *Fields of Force: The Development of a World View from Faraday to Einstein.* London: Routledge and Kegan Paul, 1974, xiv + 370 pp.

A lively survey of the development of the concept of a field from Faraday to Einstein. Is particularly concerned to delineate the "problem situation" within which each person discussed (most notably Faraday, Maxwell, Hertz, Lorentz, and Einstein) was working.

2934. Boi, Luciano. "Die Beziehungen zwischen Raum, Kontinuum und Materie im Denken Riemanns; die Äthervorstellung und die Einheit der Physik. Das Entstehen einer neuen Naturphilosophie." *Philos. Natur.* 31 (1994), no. 2, 171–216. tp [1850,1875]

The title conveys the themes: the relationships between space, continuum and matter in Riemann's thinking; the concept of ether and the unity of physics; the evolution of a new philosophy of nature.

2935. Bork, Alfred M. "Maxwell, Displacement Current, and Symmetry". *American Journal of Physics* 31 (1963), 854–859.

Argues against the statement often made in physics texts that Maxwell introduced the displacement current to make his equations symmetrical. Shows that symmetry was brought in as a consideration by Heaviside.

2936. Bork, Alfred M. "Maxwell and the Electromagnetic Wave Equation". *American Journal of Physics* 35 (1967), 844–849.

Discusses and illustrates by flow charts Maxwell's three derivations of the wave equation from the basic electromagnetic equations, in the papers of 1865 and 1868 and in the *Treatise*. See also item 3576.

2937. Bork, Alfred M. "Maxwell and the Vector Potential". *Isis* 58 (1967), 210–222.

Presents detailed evidence to show that, in contrast to a commonly expressed modern view, for Maxwell the vector potential represented not a mere mathematical construction, but a real physical quantity which had its conceptual origin in Faraday's notion of the "electrotonic state."

2938. Cannell, D. M. *George Green. Mathematician and Physicist 1793–1841. The Background to His Life and Work.* With a foreword by Lawrie Challis. London: The Athlone Press Ltd., 1993. xxvi + 265 pp.

The more technical aspects are relegated to a competent appendix but this is otherwise a comphrehensive biography of Green about whom information is scarce. Reviewed in **MR** 95j:01029.

2939. Bromberg, Joan L. "Maxwell's Displacement Current and His Theory of Light". *Archive for History of Exact Sciences* 4 (1967), 218–234.

Rejects, on the basis of a detailed analysis of the relevant parts of Maxwell's published papers, the accounts usually given of the introduction by him of the displacement current, arguing that he introduced it not on aesthetic grounds or in order to obtain a consistent set of equations but for pragmatic reasons, as a plausible method of advancing his calculations. Points to errors and serious confusions in Maxwell's initial presentation of the idea, and shows how these were gradually eliminated in his later publications on electromagnetism. See also item 3579.

2940. Bromberg, Joan L. "Maxwell's Electrostatics". *American Journal of Physics* 36 (1968), 142–151.

Argues that there is "a real and fundamental ambiguity, contradiction, or obscurity" in each of Maxwell's major discussions of electrostatics, but a different one in each. Finally, in the *Treatise*, Maxwell's equations mask his physical ideas. Displacement was initially introduced as a synonym for dielectric displacement. In later versions of the theory, however, Maxwell altered the signs appearing in his equations in such a way as to render those governing displacement incompatible with his earlier conception. As a result, displacement came to be seen by his successors as a conception original with him, and his intended meaning became lost.

2941. Buchwald, Jed Z. "William Thomson and the Mathematization of Faraday's Electrostatics". *Historical Studies in the Physical Sciences* 8 (1977), 101–136.

Argues that Thomson's application of Fourier's heat diffusion equation to electrostatics did not arise from an attempt to express Faraday's ideas about electric force in mathematical terms. Rather, his primary purpose initially was to use Laplace's theory of attraction to solve a problem in heat theory. Only subsequently, when he became aware of the difficulties associated with Poisson's conception of a physical layer of electric fluid on the surface of a conductor, did he abandon the fluid theory of electricity and seek to reconcile Green's analyses based on the notion of potential with Faraday's doctrines.

2942. Buchwald, Jed Z. *From Maxwell to Microphysics. Aspects of Electromagnetic Theory in the Last Quarter of the Nineteenth Century.* Chicago, Ill.: University of Chicago Press, 1985. xv + 339 pp.

Reviewed by S. D. Chatterji in **MR** 87d:01015.

2943. Campbell, Lewis, and William Garnett. *The Life of James Clerk Maxwell.* London: Macmillan, 1882, xvi + 662 pp. 2nd ed., abridged and rev. London: Macmillan, 1884. 1st ed. reprinted with a preface by Robert H. Kargon. New York and London: Johnson Reprint Corp., 1969.

Contains (1) a narrative *Life*, which includes many letters to Lewis Campbell and others, by Campbell, a boyhood friend and lifelong correspondent of Maxwell; (2) an account of Maxwell's scientific work, by Garnett, one of his students at Cambridge; (3) a selection of his poetry. In the second edition, Garnett's contribution was greatly condensed and distributed throughout the biography, and seven new letters (including four to Faraday) added. These have also been included in the reprint edition.

2944. Caneva, Kenneth L. "From Galvanism to Electrodynamics: The Transformation of German Physics and Its Social Context". *Historical Studies in the Physical Sciences* 9 (1978), 63–159.

On the basis of German writings on electricity and magnetism from the first half of the 19th century, delineates two very different styles in German physics during this period, namely, "concretizing science," which was qualitative in character and asserted experience as the direct source of theory, and "abstracting science," which was quantitative, mathematical, and hypothetico-deductive in structure. Argues that these were maintained by two different generational groups, and links the change in scientific outlook from one generation to the next with wider changes in German culture and society following the Napoleonic invasions.

2945. Chalmers, A. F. "The Electromagnetic Theory of James Clerk Maxwell and Some Aspects of Its Subsequent Development". Dissertation, University of London, 1971.

Provides the basis for items 2946 and 2947. Includes in addition a chapter on "The Subsequent Extension of Maxwell's Theory," in which Helmholtz's theory of a polarizable ether, seen as a compromise between the action at a distance and continuous field theories, is presented as the crucial link between the work of Maxwell and that of Hertz and Lorentz.

2946. Chalmers, A. F. "The Limitations of Maxwell's Electromagnetic Theory". *Isis* 64 (1973), 469–483.

Identifies several different limitations of Maxwell's theory, including (1) Maxwell's conception that light was a mechanical state of the ether arising from a mechanical interaction between the matter of the source and the surrounding ether, and not from *electrical* disturbances, meant that he failed to recognize the possibility of electromagnetic radiation; (2) his conception of charge was vague and unsatisfactory; yet (3) despite its vagueness, it was precise enough to lead to some falsifiable (and ultimately falsified) conclusions. These limitations are attributed to the theory's being, ironically, too much a theory about mechanisms in the aether, as a result of which it lacked important elements provided by the rival action-at-a-distance theory.

2947. Chalmers, A. F. "Maxwell's Methodology and His Application of It to Electromagnetism". *Studies in History and Philosophy of Science* 4 (1973), 107–164.

Argues that Maxwell's innovations in electromagnetism were achieved in spite of the methodology to which he purportedly ascribed: in particular, *contra* Duhem, Maxwell was led to the concept of displacement and hence the idea that light was an electromagnetic phenomenon, not by his various attempts to reduce electricity and magnetism to the principles of mechanics, but by arguments arising within the science of electricity itself. Analyzes a number of persisting (and connected) difficulties in Maxwell's notions of displacement and charge, arguing that Maxwell was actually hindered from resolving these by his methodological views.

2948. Cuvaj, Camillo. "Henri Poincaré's Mathematical Contributions to Relativity and the Poincaré Stresses". *American Journal of Physics* 36 (1968), 1102–1113.

Gives a summary account of some of the main achievements in Poincaré's major paper (published 1906) on the theory of the electron. An addendum, with a list of corrections, was published in *American Journal of Physics* 38 (1970), 774–775.

2949. Doran, B. G. "Origins and Consolidation of Field Theory in Nineteenth-Century Britain: From the Mechanical to the Electromagnetic View of Nature". *Historical Studies in the Physical Sciences* 6 (1975), 132–260.

A general and non-mathematical account in which Larmor's work in the 1890s is portrayed as the culmination of a long tradition in British physics of non-mechanical theories of the ether. The argument rests, however, on a number of dubious re-interpretations of earlier workers.

2950. Duhem, Pierre. *Les théories électriques de J. Clerk Maxwell: Etude historique et critique*. Paris: A. Hermann, 1902.

A polemical critique of Maxwell's ideas.

2951. Everitt, C. W. F. *James Clerk Maxwell: Physicist and Natural Philosopher*. New York: Charles Scribner's Sons, 1975.

An expanded version of the "Maxwell" entry in the *Dictionary of Scientific Biography*, item 8. An excellent survey of Maxwell's life and scientific work.

2952. Gillispie, Charles Coulston. *The Edge of Objectivity: An Essay in the History of Scientific Ideas*. Princeton, N.J.: Princeton University Press, 1960, 562 pp.

A justly esteemed work which includes (pp. 458–492) a section on Maxwell in which he is presented as "the ultimate impresario of classical physics, who brought the chief characters, the atom and the ether, to the center of the stage, and there left them all exposed to the winds of criticism blowing up out of positivism." See also item 2219.

2953. Gillmor, C. Stewart. *Coulomb and the Evolution of Physics and Engineering in 18th-Century France*. Princeton, N.J.: Princeton University Press, 1971, xvii + 328 pp.

A well-researched biography, together with analyses of Coulomb's various contributions to physics and engineering. Argues that mathematical physics emerged in late 18th-century France from an amalgamation of three previously separate traditions, namely, rational mechanics, experimental physics, and practical engineering, and that Coulomb, with his strong background in engineering, played a seminal role in this. See also item 3231.

2954. Goldberg, Stanley. "The Abraham Theory of the Electron: The Symbiosis of Experiment and Theory". *Archive for History of Exact Sciences* 7 (1970), 7–25.

Shows how Abraham (1875–1922) attempted to derive a wholly electrodynamic basis for mechanics on the assumption of a rigid electron, Maxwell's equations, and an absolute frame of reference determined by the ether. Contrasts Abraham's views with Lorentz's theory based on a deformable electron, assesses the relationship between his work and Kaufmann's experimental investigations, and discusses the limitations of his approach.

2955. Goldberg, Stanley. "The Lorentz Theory of Electrons and Einstein's Theory of Relativity". *American Journal of Physics* 37 (1969), 982–994.

Reviews the development of Lorentz's theory of electrons insofar as it relates to the electrodynamics of moving bodies. Argues that the principle of relativity did not play an important role in Lorentz's theory, and that though Lorentz eventually realized the distinctions between his own work and that of Einstein, he was unwilling to embrace Einstein's formulation completely and thereby to reject the ether.

2956. Goldberg, Stanley. "In Defense of Ether: The British Response to Einstein's Special Theory of Relativity, 1905–1911". *Historical Studies in the Physical Sciences* 2 (1970), 89–125.

Shows that in Britain in these years Einstein's theory was largely neglected, and the concept of the ether generally maintained. Attributes British slowness to come to terms with Einstein to the fact that most British theoreticians were trained at Cambridge, and that through the Tripos examinations their training was directed chiefly at questions of ether mechanics.

2957. Green, H. Gwynedd. "A Biography of George Green, Mathematical Physicist of Nottingham and Cambridge, 1793–1841". In *Studies and Essays in History of Science and Learning Offered in Homage to George Sarton....* Edited by M. F. Ashley Montagu. New York: Henry Schuman, 1946, 549–594.

A brief (18-page) account of Green's career, unfortunately entirely lacking in technical discussion of his work, together with various documents relating to his life. Also includes extracts from Lord Kelvin's correspondence concerning his re-discovery of Green's subsequently renowned *Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism* (1828).

2958. Haas-Lorentz, G. L. de, ed. *H. A. Lorentz—Impressions of His Life and Work*. Amsterdam: North-Holland, 1957, 172 pp.

Reminiscences of Lorentz by his daughter and others who knew him, with a chapter on "The Scientific Work," without any mathematical details, by A. D. Fokker.

2959. Heilbron, John L. *Electricity in the 17th and 18th Centuries: A Study of Early Modern Physics*. Berkeley, Los Angeles, London: University of California Press, 1979, xiv + 606 pp.

An outstanding and comprehensive history of electricity to about the year 1800, including perceptive discussions of the conceptual difficulties confronting those who wished to quantify the subject and of the mathematizing activities of Aepinus, Cavendish, Coulomb, and Poisson.

2960. Heimann (Harman), P. M. "Maxwell and the Modes of Consistent Representation". *Archive for History of Exact Sciences* 6 (1969–1970), 171–213.

Argues that there was a "fundamental dichotomy" in Maxwell's thinking on electromagnetism, whereby on some occasions he took lines of force to be the basic entities of the theory and on others he sought to reduce these to states of polarization of particles of matter and ether.

2961. Heimann (Harman), P. M. “Maxwell, Hertz, and the Nature of Electricity”. *Isis* 62 (1971), 149–157.

Emphasizes the contradictions in Maxwell’s discussions of the nature of electricity in his *Treatise* and elsewhere, and argues that Hertz’s desire to eliminate these was fundamental to his reformulation of Maxwell’s theory.

2962. Hesse, Mary B. *Forces and Fields: The Concept of Action at a Distance in the History of Physics*. London: Thomas Nelson & Sons, 1961, x + 318 pp.

Chap. VIII (pp. 189–225) is devoted to “The Field Theories,” and includes a brief summary of the tension in 19th-century electromagnetic theory between action-at-a-distance and field conceptions.

2963. Hesse, Mary B. “Logic of Discovery in Maxwell’s Electromagnetic Theory”. In *Foundations of Scientific Method: The Nineteenth Century*. Edited by Ronald N. Giere and Richard S. Westfall. Bloomington, London: Indiana University Press, 1973, 86–114.

Investigates Maxwell’s explicit discussions of physical method and their application in his electromagnetic theory. Argues that, in his mature theory, Maxwell attempted to justify his introduction of the displacement current by a generalized method of induction and analogy, and by no means regarded the idea as a hypothetical concept.

2964. Hirosige, Tetu. “Electrodynamics before the Theory of Relativity, 1890–1905”. *Japanese Studies in the History of Science* 5 (1966), 1–49.

Presents three alternative schemes of thought guiding electrodynamics during this period, namely, (1) Hertz’s axiomatic approach, (2) Larmor’s etherial dynamics, and (3) Lorentz’s and Wiechert’s theory of electrons. Describes how Lorentz’s theory came to be widely (but by no means universally) accepted shortly after 1900, and shows how this carried with it the view that the ether was merely the seat of the electromagnetic field, and not, after all, a mechanical substance.

2965. Hirosige, Tetu. “Origins of Lorentz’s Theory of Electrons and the Concept of the Electromagnetic Field”. *Historical Studies in the Physical Sciences* 1 (1969), 151–209.

An excellent analysis of the evolution of Lorentz’s ideas on electromagnetism, from his early work on an electromagnetic theory of optics based on an action-at-a-distance conception, up to his major presentation of the electron theory in 1895. Concentrates particularly on Lorentz’s gradual conceptualization of the electromagnetic field as a dynamical state of a stationary aether devoid of all mechanical qualities, rather than as a mechanical system in the ether as it was for Maxwell.

2966. Hirosige, Tetu. "The Ether Problem, the Mechanistic Worldview, and the Origins of the Theory of Relativity". *Historical Studies in the Physical Sciences* 7 (1976), 3–82.

A comprehensive survey of the nineteenth-century background to the work of Lorentz, Poincaré, and Einstein on the "ether problem" and relativity. Argues that while both Lorentz and Poincaré were working within a traditional problem situation which tried to reduce electromagnetism to mechanics (or vice versa), Einstein was not. On the contrary, under the influence of Mach's critique of the mechanistic world view—seen here as much more important for Einstein than his criticisms of absolute space and time—Einstein was seeking a unification of electromagnetism and mechanics "at a higher level" where the two theories were considered to be of equal standing.

2967. Hoppe, Edmund. *Geschichte der Elektrizität.* Leipzig: J. A. Barth, 1884, xx + 622 pp.

A thorough and very comprehensive general history of electricity up to the discovery of conservation of energy and Weber's electric force "law". Concludes with a substantial section on 19th-century technical applications.

2968. Jammer, Max. *Concepts of Mass in Classical and Modern Physics.* Cambridge, Mass.: Harvard University Press, 1961, 230 pp.

Contains a chapter (pp. 136–153) on "The Electromagnetic Concept of Mass," in which the work of Heaviside and Abraham in particular is described.

2969. Jones, H. Bence. *Life and Letters of Faraday.* London: Longmans, Green and Co., 1870, x + 427 pp.; viii + 499 pp. 2 vols.

A "biography" constructed almost entirely out of Faraday's own letters and journals, with short linking passages.

2970. Kargon, Robert. "Model and Analogy in Victorian Science: Maxwell's Critique of the French Physicists". *Journal of the History of Ideas* 30 (1969), 423–436.

Includes a section (pp. 431–436) on "Maxwell and the Electromagnetic Field" in which Maxwell's attitude towards his mechanical models is discussed.

2971. Kastler, Alfred. "Ampère et les lois de l'électrodynamique". *Revue d'histoire des sciences et de leurs applications* 30 (1977), 143–157.

An exposition of Ampère's route to his law of force between current elements, summarizing Ampère's own account in his *Mémoire sur la théorie mathématique des phénomènes électrodynamiques, uniquement déduite de l'expérience.*

2972. Knudsen, Ole. "From Lord Kelvin's Notebook: Ether Speculations". *Centaurus* 16 (1971), 41–53.

Publishes a brief extract from one of Kelvin's notebooks, together with a brief commentary and explanatory notes. The passage in question is dated January 6, 1859, and Kelvin appears to have written it out in order to clarify his own thinking. In it, he sets out his notion of the ether as an ideal elastic substance which he wishes to substitute for the traditional conception of the ether as made up of discrete particles exerting forces on each other at a distance. The Faraday effect figures prominently in his discussion.

2973. Knudsen, Ole. "The Faraday Effect and Physical Theory". *Archive for History of Exact Sciences* 15 (1976), 235–281.

Emphasizes the role played by the Faraday effect in the development of Maxwell's electromagnetic theory, namely, that it convinced him that the magnetic field was constituted of aetherial vortices. Argues that it was this conviction that lay behind Maxwell's well-known difficulties concerning the nature of electricity which, it is shown, vitiated even his detailed analysis of the Faraday effect itself. Contrasts Maxwell's problems here with the power of the Contintental action-at-a-distance approach displayed in Carl Neumann's analysis of the same effect.

2974. Knudsen, Ole. "Electric Displacement and the Development of Optics after Maxwell". *Centaurus* 22 (1978), 53–60.

Argues that Maxwell's concept of displacement was of a real physical quantity representing the polarization of the ether and with no specific connection with matter. Gibbs in his papers on electromagnetic optics followed this, but Lorentz, following Helmholtz, regarded displacement as a composite with distinct components of polarization in both matter and the ether. The separation of the two helped pave the way for the electron theory.

2975. Knudsen, Ole. "19th Century Views on Induction in Moving Conductors". *Centaurus* 24 (1980), 346–360.

Takes as his starting point the opening paragraph of Einstein's 1905 relativity paper containing his famous comments about an asymmetry in the classical treatment of electromagnetic induction. Shows that questions of symmetry and invariance in connection with electromagnetic induction had been discussed by a number of 19th-century authors, and points to a general feature of these discussions, namely, their linking of the problem of induction with the question of the relationship between the motions of matter and the aether.

2976. Koenigsberger, Leo. *Hermann von Helmholtz*. Braunschweig: Friedrich Vieweg und Sohn, 1902–1903. 3 vols. A 1-vol. English translation and abridgement by Francis A. Welby, Oxford: Clarendon Press, 1906.

The standard biography, including long extracts from Helmholtz's papers and correspondence. (These are considerably abbreviated in the English edition.)

2977. Lützen, Jesper. "Heaviside's Operational Calculus and the Attempts to Rigorise It". *Archive for History of Exact Sciences* 21 (1979–1980), 161–200.

Examines several examples of Heaviside's non-rigorous use of the basics of operational calculus in electrical calculations, showing his extensive reliance on physical intuition. Traces the efforts of later mathematicians to render these techniques more rigorous. See also item 2909.

2978. McCormmach, Russell. "The Electrical Researches of Henry Cavendish". Dissertation, Case Western Reserve University, 1967.

A comprehensive analysis of Cavendish's electrical investigations, based on a thorough study of Cavendish's manuscripts, as well as on Maxwell's published edition of the electrical papers.

2979. McCormmach, Russell. "J. J. Thomson and the Structure of Light". *British Journal for the History of Science* 3 (1967), 362–387.

Describes Thomson's speculations concerning a discontinuous structure in the electromagnetic field, based upon the presumed discreteness of Faraday-style tubes of force and leading to the view that light was granular in character. Discusses the relationship between Thomson's ideas and Einstein's notion of light quanta, suggesting that even though Thomson resolutely opposed the quantum theory, the familiarity of British physicists with his own ideas about light helped reconcile them to it.

2980. McCormmach, Russell. "H. A. Lorentz and the Electromagnetic View of Nature". *Isis* 61 (1970), 458–497.

An authoritative study of Lorentz's development of the electron theory as the foundation of a universal purely electromagnetic physics. The inherently non-mechanical character of the theory is emphasized, as is the authoritative position it came to occupy in physics, especially in Germany, around 1900.

2981. McCormmach, Russell. "Einstein, Lorentz, and the Electron Theory". *Historical Studies in the Physical Sciences* 2 (1970), 41–87.

An exceptionally clear account of the evolution of Einstein's thought during the first ten years of the 20th century. Emphasizes the central place of electrodynamics in the problem situations with which Einstein was concerned, and the importance of Lorentz's work to him, even in those situations where he deviated most sharply from Lorentz's conceptions.

2982. McGuire, J. E. "Forces, Powers, Aethers, and Fields". In *Methodological and Historical Essays in the Natural and Social Sciences*. Edited by Robert S. Cohen and Marx W. Wartofsky. (Boston Studies in the Philosophy of Science, XIV.) Dordrecht, Boston: D. Reidel, 1974, 119–159.

An attempt to isolate "some of the turning points in the history of the emergence of field concepts as a prolegomenon to understanding the dynamics of conceptual change involved." Includes a discussion (which draws heavily on Heimann's work, item 2960) of the ideas of Maxwell, and, much more briefly, an account of the ideas of Poynting, J. J. Thomson, Larmor, and Lorentz.

2983. Merleau-Ponty, Jacques. *Leçons sur la genèse des théories physiques: Galilée, Ampère, Einstein.* Paris: Vrin, 1974, 172 pp.

Includes (pp. 69–112) an interesting discussion of Ampère's *Théorie mathématique des phénomènes électro-dynamiques* (1827), viewing this as illustrative of one of the characteristic stages in the formation of modern physical theory in which the Galilean objective of mathematizing experimental knowledge is accepted, but in which a new problem arises where, with this objective in mind, a choice has to be made between different modes of conceptualizing the situation.

2984. Miller, Arthur I. "A Study of Henri Poincaré's 'Sur la dynamique de l'électron.'" *Archive for History of Exact Sciences* 10 (1973), 207–328.

A detailed discussion, in its historical context, of Poincaré's notable attempt to formulate a purely electromagnetic theory of a deformable electron. The paper includes extended analyses of earlier theories of the electron due to Abraham and Lorentz, and evidence for the influence of Poincaré's work despite its being soon overtaken by Einstein's. Emphasizes Poincaré's adherence to an electromagnetic world-picture in which the principle of relativity was a law open to experimental verification.

2985. Miller, Arthur I. *Albert Einstein's Special Theory of Relativity: Emergence (1905) and Early Interpretation (1905–1911).* Reading, Mass.: Addison-Wesley, 1981, xxviii + 466 pp.

A "biography" of Einstein's 1905 relativity paper that includes a long introductory chapter (pp. 11–121), with considerable mathematical detail, on "Electrodynamics: 1890–1905." This surveys the theoretical contributions of Lorentz, Poincaré, and Abraham and their interaction with the experimental work of Kaufmann.

2986. Miller, John David. "Rowland and the Nature of Electric Currents". *Isis* 63 (1972), 5–27.

An account, based on then recently discovered manuscript sources, of Rowland's lifelong concern with experimental investigations of the nature of electric currents, especially through his efforts to demonstrate magnetic effects due to moving electric charges.

2987. Miller, John David. "Rowland's Magnetic Analogy to Ohm's Law". *Isis* 66 (1975), 230–241.

Describes how Rowland attempted to translate into mathematical form Faraday's analogy between a magnet and its surrounding force field and a voltaic battery immersed in water, arriving ultimately at the conclusion that magnetic induction is related to the magnetic potential between two points by a law exactly analogous to Ohm's law for electrical currents.

2988. Molella, Arthur Philip. "Philosophy and Nineteenth-Century German Electrodynamics: The Problem of Atomic Action at a Distance". Dissertation, Cornell University, 1972, 263 pp.

Focuses on the interaction between Weber's theory of electrodynamic action at a distance between "atoms" of electricity and contemporary German philosophical atomism, especially as expounded by G. T. Fechner and J. F. C. Zöllner.

2989. Moyer, Donald Franklin. "Energy, Dynamics, Hidden Machinery: Rankine, Thomson and Tait, Maxwell". *Studies in History and Philosophy of Science* 8 (1977), 251–268.

Discusses the role of generalized equations of motion in Maxwell's electrodynamics (following earlier suggestions by Rankine and Thomson and Tait) as a method of generating mechanical explanations even though the underlying machinery remains hidden.

2990. Moyer, Donald Franklin. "Continuum Mechanics and Field Theory: Thomson and Maxwell". *Studies in History and Philosophy of Science* 9 (1978), 35–50.

Briefly discusses some nineteenth-century developments in continuum mechanics, especially those due to William Thomson, and shows how Maxwell used a generalized form of Thomson's line of reasoning to construct the electromagnetic theory set out in his *Treatise.* See also item 3251.

2991. Olesko, Kathryn Mary. "The Emergence of Theoretical Physics in Germany: Franz Neumann and the Königsberg School of Physics, 1830–1890". Dissertation, Cornell University, 1980, 545 pp.

An outstanding thesis based on extensive research on previously untapped archival material. Includes some discussion of Neumann's contribution to electromagnetic theory, but the emphasis throughout is on wider questions concerning the conceptualization of physics as a mathematical science and the institutionalization of the new approach.

2992. Pihl, Mogens. *Der Physiker L. V. Lorenz.* Copenhagen: Einar Munksgaard, 1939, 128 pp.

A University of Copenhagen physics doctoral thesis. Includes a brief (3 pages) biographical outline of Lorenz and a bibliography of his writings on physical subjects, together with critical analyses of his work on optics, the conductivity of metals, and kinetic and elasticity theory. Seeks throughout to clarify Lorenz's ideas by translating them into less complicated and more satisfactory modern mathematical form.

2993. Pihl, Mogens. "The Scientific Achievements of L. V. Lorenz". *Centaurus* 17 (1972), 83–94.

A brief account, in English, of Lorenz's principal contributions to mathematical physics, especially in optics, the electromagnetic theory of light, conductivity, and the theory of telephone cables.

2994. Pyenson, Lewis. "Physics in the Shadow of Mathematics: The Göttingen Electron-Theory Seminar of 1905". *Archive for History of Exact Sciences* 21 (1979), 55–89.

Describes the material studied at the seminar as a summary of immediately pre-Einsteinian electron theory—mainly the work of Hertz, Abraham, Schwarzschild, Sommerfeld, and, above all, Lorentz—and argues that the failure of the group to resolve in a satisfactory manner the outstanding problems of electromagnetic theory was due to their over-emphasizing the purely mathematical techniques involved, at the expense of physical theory. See also item 3753.

2995. Rosenfeld, L. "The Velocity of Light and the Evolution of Electrodynamics". *Nuovo Cimento. Supplemento (Società italiana di fisica)* 4 (1956), 1630–1669.

Discusses the developments leading up to Maxwell's identification of light as an electromagnetic phenomenon, and also the less familiar story of Lorenz's independently arriving at the same conclusion by a different route. Stresses the importance for both men of a dynamical conception of nature which a few years later, in Hertz's day, was on the wane.

2996. Schaffner, Kenneth F. "The Lorentz Electron Theory and Relativity". *American Journal of Physics* 37 (1969), 498–513.

Traces Lorentz's work on the electrodynamics of moving bodies from 1887 to 1909. Discusses the evolving role played in Lorentz's theory by the contraction hypothesis, and the type of support this enjoyed within the theory. Emphasizes the nonreciprocal character of the transformation equations in Lorentz's theory, in which the ether continues to provide a privileged reference frame.

2997. Schaffner, Kenneth F., ed. *Nineteenth-Century Aether Theories*. With a commentary by K. F. Schaffner. Oxford, New York: Pergamon Press, 1972, ix + 278 pp.

A volume in the Commonwealth and International Library series, "Selected Readings in Physics." Comprises an excellent 121-page introduction by Schaffner, together with extracts from the writings of Fresnel, Stokes, Michelson and Morley, Green, MacCullagh, W. Thomson, Fitzgerald, Heaviside, Larmor, and Lorentz.

2998. Schaffner, Kenneth F. "Outlines of a Logic of Comparative Theory Evaluation with Special Attention to Pre- and Post-Relativistic Electrodynamics". *Historical and Philosophical Perspectives of Science*. Edited by R. H. Stuewer. (Minnesota Studies in the Philosophy of Science, Vol. 5.) Minneapolis: University of Minnesota Press, 1970, 311–354.

Uses the logic to assess the relative standing in 1905 of Lorentz's and Einstein's electrodynamic theories, concluding that the former ranked higher in "theoretical context sufficiency" and the latter in simplicity considerations.

2999. Siegel, Daniel M. "Classical-Electromagnetic and Relativistic Approaches to the Problem of Nonintegral Atomic Masses". *Historical Studies in the Physical Sciences* 9 (1978), 323–360.

Discusses the competing answers provided by classical electromagnetic theory (in which, following Lorentz, all mass is regarded as electromagnetic) and relativity theory, to the question of why atomic masses are not integral multiples of the mass of the hydrogen atom. These answers at first developed independently, but from 1916 they interacted. Not until the 1930s did the relativistic approach prevail. It is emphasized, following McCormmach, that in the early days of relativity theory, Lorentz's theory "was not some hoary predecessor, but rather a near contemporary, just as new and full of promise.

3000. Siegel, Daniel M. "Text and Context in Maxwell's Electromagnetic Theory. Aspects of Mid to Late Nineteenth Century Electromagnetism." *Physis Riv. Internaz. Storia Sci.* (N.S.) 33 (1996), no. 1-3, 125–140.

Maxwell's work is used to show how "texts in mathematical physics must not only be read, they must be performed [where] performance consists of expanding the text, by filling in missing steps in the mathematical argument, while in the process rendering the text, through translation into the reader's own preferred mathematical notation."

3001. Simpson, Thomas K. "Maxwell and the Direct Experimental Test of His Electromagnetic Theory". *Isis* 57 (1966), 411–432.

Reports the results of an unsuccessful effort to trace any of Maxwell's speculations concerning the possibility of a direct experimental verification of his theory of electromagnetic propagation through a medium. Shows that many of the materials required for such direct experimentation were available in Maxwell's day, and takes his silence concerning them as evidence that his preoccupations were with different questions, and in particular with the nature of light rather than with electromagnetic phenomena for their own sake.

3002. Simpson, Thomas K. "A Critical Study of Maxwell's Dynamical Theory of the Electromagnetic Field in the *Treatise on Electricity and Magnetism*". Dissertation, Johns Hopkins University, 1968, 604 pp.

Interprets Maxwell's *Treatise* as a systematic attempt to articulate Faraday's insights in the language of formal mathematical physics. Delineates two different phases in Maxwell's presentation of the dynamical theory in the *Treatise*, one inductive, the second deductive, with the dynamical theory proper appearing in the latter. This two-part form is seen to correspond to Maxwell's wider philosophy of science; the first phase is intended to uncover *a priori* intuitions of fundamental ideas from which the subsequent deductive phase can proceed.

3003. Simpson, Thomas K. "Some Observations on Maxwell's *Treatise on Electricity and Magnetism*". *Studies in History and Philosophy of Science* 1 (1970), 249–263.

An article abstracted from the author's doctoral thesis (see previous entry). Discusses the relationship between Maxwell's metaphysics and his use of Lagrangian methods in developing his dynamical theory of the electromagnetic field. Argues that, for Maxwell, "the Lagrangian mode of the dynamical theory is not ... simply a convenience for an imperfect stage of a science; it is the appropriate mode for human knowledge of nature, which is essentially relative".

3004. Spitzer, Paul Georg. *Joseph John Thomson: An Unfinished Social and Intellectual Biography.* Dissertation, Johns Hopkins University, 1970, 244 pp.

Discusses the social and intellectual milieu in which Thomson rose to prominence, with much detail concerning the style and social position of physics in late Victorian Cambridge, though without reference to Thomson's private papers and correspondence or to other unpublished material. Analyzes, without giving mathematical details, Thomson's publications up to the late 1880s. These are seen as very conventional in character.

3005. Stine, Wilbur Morris. *The Contributions of H. F. E. Lenz to Electromagnetism*. Philadelphia: The Acorn Press, 1923, 157 pp.

Includes a very sketchy biographical chapter, together with a bibliography of Lenz's scientific publications and an account, unfortunately historically exceedingly naive and with little mathematical detail, of his major papers on electromagnetism.

3006. Tazzioli, Rossana. "Ether and Theory of Elasticity in Beltrami's work." *Arch. Hist. Exact Sci.* 46 (1993), no. 1, 1–37.

Developments of differential geometry as they relate to the ether concept of Maxwell. Reviewed by Gerard A. Maugin in **MR** 94i:73003.

3007. Thompson, Silvanus P. *The Life of William Thomson, Baron Kelvin of Largs*. London: Macmillan, 1910, xx + 1,297 pp. 2 vols.

A typical "life and letters" in the Victorian style and on a grand scale, with generous quotations throughout from Thomson's letters. Appendices list his various academic and other distinctions, his publications (661 items), and patents granted to him.

3008. Topper, David Roy. "J. J. Thomson and Maxwell's Electromagnetic Theory". Dissertation, Case Western Reserve University, 1970, 184 pp.

Describes Maxwell's work in electromagnetism, emphasizing his use in his later papers of the Lagrangian formulation in order to ground the theory satisfactorily on dynamical principles while yet remaining ignorant of the actual mechanical systems presumed to be involved. Shows how Thomson extended this approach in order to show, through the use of cyclic coordinates, that potential energy is formally equivalent to the kinetic energy of hidden motions; and how on this basis he banished forces from his dynamical theory in favor of etherial vortex motions and the like. Argues that Thomson, far from upholding an electromagnetic theory of matter, remained unfailingly committed to the classical program of reducing electromagnetism to dynamical principles.

3009. Topper, David Roy. "Commitment to Mechanism: J. J. Thomson, the Early Years". *Archive for History of Exact Sciences* 7 (1971), 393–410.

An article abstracted from the author's doctoral thesis (see item 3008). Argues that Thomson was committed from the outset of his career to giving a complete mechanical explanation of electromagnetic phenomena, and shows how he accomplished this in a mathematical proof involving the use of cyclic coordinates in Lagrange's equations in order to reduce the potential energy term (and hence the concept of force) to kinetic energy, interpreted as the kinetic energy of hidden motions.

3010. Tricker, R. A. R. *Early Electrodynamics: The First Law of Circulation*. Oxford: Pergamon, 1965, x + 217 pp.

Deals with the development of Ampère's theory of the electrodynamics of steady currents. Includes extensive extracts from Ampère's writings and those of Biot and Savart, shorter ones from papers by Oersted (1820) and H. Grassmann (1845), two short chapters setting the historical stage, and an 89-page commentary. The latter is not purely historical, but is also concerned with elucidating the logical status of the theory.

3011. Tricker, R. A. R. *The Contributions of Faraday and Maxwell to Electrical Science*. Oxford: Pergamon, 1966, x + 289 pp.

Includes biographical sketches of both Faraday and Maxwell, straightforward accounts of their work on electromagnetism, and extracts from their chief writings on the subject. Also has an interesting chapter on "The Logical Status of the Law of Electromagnetic Induction."

3012. Turner, Joseph. "A Note on Maxwell's Interpretation of Some Attempts at Dynamical Explanation". *Annals of Science* 11 (1955), 238–245.

Discusses the constraints that Maxwell imposed on the invention of dynamical explanations in physics, especially his requirements (1) that the mechanism proposed be a "consistent representation" in the sense that it is consistent with the fundamental principles of dynamics and (2) that there be some independent evidence for it.

3013. Turner, Joseph. "Maxwell on the Logic of Dynamical Explanation". *Philosophy of Science* 23 (1956), 36–47.

A brief but exceptionally clear exposition of Maxwell's attitude towards his theories, drawing for this purpose the following useful distinctions: (1) a *physical analogy* is a relation between a branch of one science and a branch of another, such that both branches possess the same mathematical form; (2) a *dynamical analogy* is a physical analogy in which one of the branches of science involved is a branch of dynamics; (3) a *dynamical explanation* is a dynamical analogy taken literally. In these terms, Maxwell's 1861 paper is seen as an attempt to provide a dynamical explanation of electromagnetism, while his 1864 paper has the more modest aim of providing a dynamical analogy.

3014. Turner, Joseph. "Maxwell on the Method of Physical Analogy". *British Journal for the Philosophy of Science* 6 (1956), 226–238.

An elaboration of Maxwell's views on the nature and usefulness of physical analogies.

3015. Wangerin, Albert. *Franz Neumann und sein Wirken als Forscher und Lehrer*. Braunschweig: F. Vieweg und Sohn, 1907, x + 185 pp.

Comprises an outline of Neumann's career as "the first exponent of theoretical physics in Germany"; a systematic survey of his published work on crystallography, heat, optics (especially the optical behavior of crystals), and electromagnetism, and in pure mathematics; brief summaries of his lectures as published by his students; a 30-page history of his renowned Königsberg seminar on theoretical physics; and a brief account of his lifelong struggle to have a physics laboratory erected at Königsberg.

3016. Whittaker, Sir Edmund Taylor. *A History of the Theories of Aether and Electricity. Vol I: The Classical Theories. Vol. II: The Modern Theories 1900–1926.* London: Thomas Nelson & Sons, 1951–1953. Reprinted New York: Harper Torchbooks, 1960, 434 pp.; 310 pp. 2 vols.

Volume I is a revised edition of a work first published in 1910 under the title *A History of the Theories of Aether and Electricity, from the Age of Descartes to the Close of the Nineteenth Century.* Still the standard history of the subject, and likely to remain so even though recent historiography has challenged some of its premises and recent scholarship some of its conclusions. The treatment of Einstein in Volume II is, however, notoriously unfair. See also items 3611, 3746.

3017. Wiederkehr, Karl Heinrich. "Wilhelm Webers Stellung in der Entwicklung der Elektrizitätslehre". Dissertation, Universität Hamburg, 1960, 254 pp.

A detailed account of Weber's career and scientific work. Emphasizes the importance for Weber of his early collaboration with Gauss.

3018. Wiederkehr, Karl Heinrich. *Wilhelm Eduard Weber: Erforscher der Wellenbewegung und der Elektrizität 1804–1891.* (Grosse Naturforscher, Bd. 32.) Stuttgart: Wissenschaftliche Verlagsgesellschaft, 1967, 227 pp.

A straightforward account, without technical detail, of Weber's life and scientific work. Based on the author's doctoral dissertation, item 3017.

3019. Williams, L. Pearce. *Michael Faraday: A Biography.* London: Chapman and Hall; New York: Basic Books, 1965, xvi + 531 pp.

An outstanding intellectual biography that carefully traces the development, in interaction with his experimental investigations, of Faraday's theoretical conceptions concerning electricity and magnetism. Some of William's opinions, especially concerning the influence of Boscovich's ideas on Faraday, have proved controversial, but in general he presents a plausible account of a highly original thinker.

3020. Williams, L. Pearce. *The Origins of Field Theory.* New York: Random House, 1966, xii + 148 pp.

Intended as a college text, this work draws heavily upon the same author's much larger intellectual biography of Faraday (see item 3019), but also devotes two chapters to setting the scientific background to Faraday's work, and a concluding chapter to Maxwell's mathematization of Faraday's qualitatively expressed ideas. An excellent introduction to the subject.

3021. Wise, Matthew N. "The Flow Analogy to Electricity and Magnetism: Kelvin and Maxwell". Dissertation, Princeton University, 1977, 303 pp.

Focuses on the use by Kelvin and Maxwell (in his early work) of a flow analogy for electromagnetic forces in order to bring the mathematical techniques developed by Fourier to bear on Faraday's experimentally based conceptions. On this basis presents an interpretation of the origins of electromagnetic field theory which emphasizes the role of mathematical techniques in producing conceptual change.

3022. Woodruff, A. E. "Action at a Distance in Nineteenth Century Electrodynamics". *Isis* 53 (1962), 439–459.

Describes the developments leading up to Weber's formulation of his well-known expression for the force between two moving electric charges, and also the principal difficulties that others, especially Helmholtz and Maxwell, found in Weber's conception.

3023. Woodruff, A. E. "The Contributions of Hermann von Helmholtz to Electrodynamics". *Isis* 59 (1968), 300–311.

A good clear account which brings out the relationship of Helmholtz's work to that of his predecessors (Neumann, Weber, Maxwell) and of Hertz.

GEOMETRY

Like the subject itself, histories of geometry rapidly become specialized. The reader should consult other sections, especially for articles on Greek, Moslem, Arabic, Indian, and Chinese geometry. The references given here pertain almost exclusively to Western mathematics since 1600. Even so, some articles are listed elsewhere, under certain centuries (as, for example, a number of references to Gauss). Much recent work on the history of geometry will be found in the biographical entries in the *Dictionary of Scientific Biography*, item 8, and the *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*, item 10.

General Histories

3024. Boi, L., D. Flament, and J.-M. Salanskis. *1830–1930: A Century of Geometry. Epistemology, History and Mathematics. Papers from the International Conference held in Paris, September 18–23, 1989.* (Lecture Notes in Physics, 402.) Berlin: Springer-Verlag, 1992.

Contents: Christian Houzel, "The birth of non-Euclidean geometry" (3–21); Erhard Scholz "Riemann's vision of a new approach to geometry" (22–34); J. J. Gray, "Poincaré and Klein—groups and geometries" (35–44); David E. Rowe, "Klein, Lie, and the "Erlanger Programm"" (45–54); Bernard Teissier, "Apparent contours from Monge to Todd" (55–62); Luciano Boi, "L'espace: concept abstrait et/ou physique; la géométrie entre formalisation mathématique et étude de la nature" (65–90); F. Balibar, "Geometrie und Erfahrung (91–97); Ruth Farwell and Christopher Knee, "The geometric challenge of Riemann and Clifford" (98–106); Giorgio Israel, "Poincaré et Enriques: deux points de vue differents sur les relations entre géométrie, mecanique et physique" (107–126); Michel Paty, "Physical geometry and special relativity. Einstein et Poincaré" (127–149); Jean-Pierre Bourguignon, "Transport parallele et connexions en géométrie et en physique" (150–164); Hourya Sinaceur, "De la géométrie formelle à l'algebre abstraite" (167–174); Ludovico Geymonat, "Le principe de dualité: sa signification historique et epistemologique" (175–177); Gilles Gaston Granger, "The formal and the transcendental in mathematics" (178–183); Réné Thom, "Un panorama des mathématiques" (184–191); Klaus Volkert, "Mathematical progress as synthesis of intuition and calculus" (192–198); Hans Freudenthal, "What is space?" (201–204); Dominique Flament, "La *lineale Ausdehnungslehre* (1844) de Hermann Gunther Grassmann" (205–221); Gilles Chatelet, "La capture de l'extension comme dialectique géométrique: dimension et puissance selon l'Ausdehnung de Grassmann (1844)" (222–244); Gerhard Heinzmann, "Helmholtz and Poincaré's considerations on the genesis of geometry" (245–249); Jean-Michel Salanskis, "Le continu contre l'espace" (250–264); Gilles-Tannoudji Cohen, "Geometrical concepts in quantum physics" (267–269); Tullio Regge, "Physics and differential geometry" (270–272). "

3025. Boyer, Carl B. *History of Analytic Geometry.* New York: Scripta Mathematica, 1956.

See item 2088.

3026. Chasles, Michel. *Aperçu historique sur l'origine et le développement des méthodes en géométrie.* Brussels: Hayez, 1837. 2nd ed. Paris: Gauthier-Villars, 1875. 3. ed., conforme à la première, Paris: Gauthier-Villars et fils, 1889. Reprinted: Sceaux: Éditions Jacques Gabay, 1989.

Valuable because it is quite extensive, and has the merit of nearness to the work described. The second edition of 1875 is an unaltered version of the first edition.

3027. Coolidge, J. L. *A History of Geometrical Methods.* Oxford: Oxford University Press, 1940. Reprinted New York: Dover, 1963, xviii + 451 pp.

See item 2089.

3028. Freudenthal, H. "Geometry". *Encyclopedia Britannica*, vol. 10 (1969 ed.), 186–195.

An overview of Greek, projective, and non-Euclidean geometries, the axiomatic method, philosophical questions, geometrical transformations, and differential geometry; concludes with a brief look at topology.

3029. Kline, Morris. *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972. Reprinted New York: Oxford University Press, 1990.

Kline's work has a great deal of coverage on geometry with chapters on Projective Geometry, Coordinate Geometry, Analytic and Differential Geometry in the 18th Century, Revival of Projective Geometry, Non-Euclidean Geometry, Differential Geometry of Gauss and Riemann, Projective and Metric Geometry, Algebraic Geometry, Foundations of Geometry, Tensor Analysis and Differential Geometry, and many other related topics. See also items 902, 2225, 2300, 2345, 2720, 3812.

Special Studies

3030. Bachelard, S. *La représentation géométrique des quantités, imaginaires au début du XIX siècle.* Paris: Université de Paris, 1967.

Traces the history of the representation of complex numbers in terms of real numbers or as points in the plane, leading eventually to the formal conception of alternative ways of viewing complex quantities. An emphasis is placed on the large number of mathematicians who arrived at the idea of the geometric representation of complex numbers at about the same time, and the reaction of others to such new ideas.

3031. Bos, H. J. M. "On the Representation of Curves in Descartes' *Géométrie*". *Archive for History of Exact Sciences* 24 (1981), 295–338.

Bos discusses Descartes's work with regard to his introduction of new mechanical methods for the production of curves that were considered to be inadmissible in Greek geometry. He attempts to show the connection between this work and Descartes's general mathematical program. See also item 2123.

3032. Brill, A., and M. Noether. "Die Entwicklung der Theorie der algebraischen Funktionen in älterer und neuer Zeit". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 3 (1894), 107–566.

See item 2606.

3033. Chern, S.-S. "Differential Geometry: Its Past and Its Future". In *Actes du Congrès international des mathematiciens, Paris, 1970.* Paris: Gauthier-Villars, 1971, Vol. 1. 41–53.

Surveys some of the principal notions of differential geometry, including Lie groups, fiber bundles, and the use of variational methods.

3034. Clagett, Marshall, ed. *Nicole Oresme and the Medieval Geometry of Qualities and Motions. A Treatise on the Uniformity and Difformity of Intensities Known as Tractatus de configurationibus qualitatum.* Madison: University of Wisconsin Press, 1968.

Contains an introduction, English translation, and commentary to Oresme's *Tractatus de configurationibus qualitatum et motuum.* In addition to the geometrical treatment of motion, there are substantial philosophical discourses on aesthetics, music, and magic. This volume also contains a (partial) translation of Oresme's *Quaestiones supes geometriam Euclidis*. See also item 1728.

3035. Contro, W. S. "Von Pasch zu Hilbert". *Archive for History of Exact Sciences* 15 (1975–1976), 283–295.

Pasch's axiomatization of projective geometry was part of two distinct lines of work: the axiomatic approach of Peano in Italy and others in Germany, and the empirical approach to the study of axioms. These two lines were eventually brought together by Hilbert to form modern geometric axiomatics.

3036. Coolidge, J. L. *A History of the Conic Sections and Quadric Surfaces.* Oxford: Oxford University Press, 1945.

3037. Coxeter, H. S. M. "The Space-Time Continuum". *Historia Mathematica* 2 (1975), 289–298.

Describes the projective interpretation due to E. Study (1907) of Minkowski space, and also Schläfli's description (1858) of spaces of constant curvature.

3038. Dąmbska, I. "*An Essay on the Foundations of Geometry* de B. Russell et la critique de ce livre en France dans les années 1898–1900". *Organon* 10 (1974), 145–153.

This paper summarizes Russell's publication in 1897 of a greatly revised version of his Fellowship Examination at Trinity College, Cambridge. Couturat's review and the discussion following in *Revue de Métaphysique et de Morale* are considered. The English original with a foreword by Morris Kline is also available (New York: Dover, 1956).

3039. Dieudonné, Jean. *Cours de géométrie algébrique. I.* Paris: Presses Universitaires de France, 1974. Translated as †History of Algebraic Geometry: An Outline of the History and Development of Algebraic Geometry† by Judith Sally, Monterey, Calif.: Wadsworth Advanced Books & Software, 1985, xii + 186 pp.

Designed as an introduction to a course in modern algebraic geometry, this work is unfailingly stimulating in its presentation of projective geometry, Riemann and the birational geometry of curves, generalization to higher dimensions, the Italian school, and the rigorization of their work by Zariski and Weil, and culminates in Grothendieck's edifice.

3040. Fano, G. "Gegensatz von synthetischer und analytischer Geometrie in seiner historische Entwicklung im XIX. Jahrhundert". *Encyklopädie der mathematischen Wissenschaften*, III. AB4a. Leipzig: B. G. Teubner, 1907–1910. 221–288.

The key actors are Monge, Poncelet, Möbius, J. Steiner, and Chasles in synthetic geometry, and Möbius, Plücker, v. Staudt in analytic geometry. Algebraic geometry is also discussed through the works of Hermann Grassmann, Clebsch, et al., as are the contributions to differential geometry made by Monge, Dupin, Gauss, and Lie.

3041. Freudenthal, H. "The Main Trends in the Foundations of Geometry in the 19th Century". *Logic, Methodology, and Philosophy of Science.* Edited by E. Nagel, P. Suppes, and A. Tarski. Stanford: Stanford University Press, 1962.

A penetrating account of the origins and motivation for late 19th-century work on the foundations of geometry. The investigations of Helmholtz, Riemann, Klein, and the recognition of non-Euclidean geometry led to work of Pasch and the Italian school, and culminated in Hilbert's *Grundlagen der Geometrie.*

3042. Galuzzi, Massimo. "Il problema delle tangenti nella *Géométrie* di Descartes". *Archive for History of Exact Sciences,* 22 (1980), 37–51.

See *Isis Critical Bibliography* (1981), entry number 1738.

3043. Itard, J. *La Géométrie de Descartes.* (Les Conférences du Palais de la Découverte, Sér. D, Histoire des Sciences, No. 39.) Paris: Université de Paris, 1956, 14 pp.

3044. Jammer, M. *Concepts of Space*. Cambridge, Mass.: Harvard University Press, 1954. 2nd ed. Cambridge, Mass.: Harvard University Press, 1969, xv + 221 pp. 3rd enl. ed. New York: Dover, 1993, xvii + 261 pp. For this edition the author has written a new preface and an entirely new chapter.

Stresses the philosophy and history behind the concept, especially the theological implications of space independent of matter. Greater emphasis is placed on the ancient and medieval periods.

3045. Karzel, Helmut, and Hans-Joachim Kroll. *Geschichte der Geometrie seit Hilbert*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1988. x + 246 pp.

Linear Covers incidence geometries, order and topology, and congruence. There is an extensive bibliography, with biographical details of many of the authors, an index of names, and a subject index.

3046. Klein, F. *Elementary Mathematics from an Advanced Standpoint*. Part 2, *Geometry*. Translated by E. R. Hedrick and C. A. Noble. New York: Dover, 1939; translation of the 1925 Springer 3rd edition.

There is probably no better single introduction to Klein's intuitive, geometric approach than this best seller based on lectures primarily intended for prospective Gymnasium teachers. The "advanced standpoint" particularly refers to the outlook of Klein's Erlangen Program. Offers many key insights into work of Möbius, Plücker, Lie, and others, including of course Klein himself. Applications are stressed throughout.

3047. Klein, F. *Vorlesungen über die Entwicklung der Mathematik im 19. Jahrhundert*. Berlin: Springer Verlag, 1926–1927. 2 vols. Reprinted in 1 vol. New York: Chelsea, 1967.

This great classic thoroughly reflects the author's decidedly geometric outlook. Not only does geometry itself receive a disproportionate amount of attention (Monge and his school, Chasles and his, Möbius, Plücker, J. Steiner, Staudt, Cayley, etc.), but most of the other subjects are presented in connection with their applicability to geometry. Thus function theory and Riemann surfaces, group theory and crystallography, algebra and geometric curve theory are but a few of the many connections Klein emphasizes. The second volume illustrates the utility of the Erlangen Program and general invariant theory in mathematical physics. See also items 2299, and 2719.

3048. Kolata, G. B. "Isadore Singer and Differential Geometry". *Science* 204 (1979), 933–934.

A semi-popular discussion, based on an interview with Singer, of his research in global differential geometry and its role in the physics of elementary particles.

3049. Kötter, E. "Die Entwickelung der synthetischen Geometrie von Monge bis auf Staudt". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 5 (1896), 1–486.

Also issued separately as a book by Teubner in 1901.

3050. Lanczos, C. *Space through the Ages. The Evolution of Geometrical Ideas from Pythagoras to Hilbert and Einstein.* New York: Academic Press, 1970.

Despite the title only one-third history, two-thirds differential geometry, leading up to Einstein's theory of gravitation.

3051. Loria, Gino. *Die hauptsächlichsten Theorien der Geometrie in ihrer früheren und heutigen Entwicklung.* Translated by F. Schütte. Leipzig: B. G. Teubner, 1888.

German translation of *Il passato ed il presente delle principali teorie geometriche.*Excellent for its extensive references to mid-19th-century geometric researches.

3052. Loria, Gino. "Da Descartes e Fermat a Monge e Lagrange. Contributo alla storia della geometrica analitica". *Reale Accademica dei Lincei. Atti. Memoirie della classe di scienze fisiche, mathematiche e naturali*, Series 5, 14 (1923), 777–845.

Covers a vast array of work beginning with a background in antiquity, fundamental contributions of Descartes and Fermat, the coordinatization of the plane and 3-space, relation to the development of calculus, and the theory of algebraic curves.

3053. Loria, Gino. "Perfectionnements, evolution, metamorphoses du concept de coordonnées; Contribution à l'histoire de la géométrie analytique". *Mathematica* XVIII (1942), 125–145; XX (1944), 1–2; XXI (1945), 66–83.

3054. Mainzer, K. *Geschichte der Geometrie.* Mannheim: Bibliographisches Institut, 1980.

See item 2092.

3055. Miller, Arthur I. "The Myth of Gauss' Experiment on the Euclidean Nature of Physical Space". *Isis* 63 (1972), 345–348.

Miller scotches the myth that certain of Gauss's surveys of Hannover were used to investigate the physical nature of space.

3056. Molland, A. G. "Shifting the Foundations: Descartes' Transformation of Ancient Geometry". *Historia Mathematica* 3 (1976), 21–49.

Molland discusses Descartes' *Géométrie* with particular reference to his introduction of new mechanical methods for the production of curves in opposition to Greek ideas.

3057. Molland, A. G. "An Examination of Bradwardine's Geometry". *Archive for History of Exact Sciences* 19 (1978), 113–175.

Examines Bradwardine's *Geometria Speculativa* as an example of the medieval geometric outlook. The study is based on the edition of this work prepared in the author's Ph.D. dissertation (Cambridge University, 1967). See also item 1831.

3058. Neuenschwander, E. "Der Nachlass von Casorati (1835–1890) in Pavia". *Archive for History of Exact Sciences* 19 (1978), 1–89.

Describes the contents and significance of Casorati's nearly untouched *Nachlass*, including his correspondence with a number of foreign mathematicians and his notes on conversations with Weierstrass and Kronecker.

3059. Phillips, Esther R. "Karl M. Peterson: The Earliest Derivation of the Mainardi-Codazzi Equations and the Fundamental Theorem of Surface Theory". *Historia Mathematica* 6 (1979), 137–163.

This paper gives a detailed description of Peterson's work, notably his 1853 dissertation in which the theorem first appeared. Peterson was later an important influence on the Moscow school of mathematics. See also item 3253.

3060. Reich, K. *Die Entwicklung des Tensorkalküls. Vom absoluten Differentialkalkül zur Relativitätstheorie.* Vol. 11. (Science Networks.) Basel: Birkhäuser, 1994.

On the development of the tensor calculus and differential geometry, this is a thorough survey with careful summaries and well-chosen extracts of the major papers (Gauss, Riemann). The subject is divided into the theory of curves; curvature of surfaces; applicability of surfaces; geodesics; minimal surfaces; orthogonal systems; and other special surfaces. Large bibliography and a useful index. See item 3742.

3061. Richards, J. "The Evolution of Empiricism: Hermann von Helmholtz and the Foundations of Geometry". *British Journal for the Philosophy of Science* 28 (1977), 235–253.

Stresses the empirical component in Helmholtz's geometric theories, and shows how his researches were integrated around problems in the physiology of perception. This led him to a variety of investigations, and in particular to the geometry of physical space. Also discusses influences of Kant and Riemann.

3062. Scholz, Erhard. *Geschichte des Mannigfaltigkeitsbegriffs von Riemann bis Poincaré.* Boston: Birkhäuser, 1980.

Photo-printed from a typed manuscript, this work was originally produced as a dissertation at the Mathematical Institute of Bonn University, Germany, in 1979. It opens with a discussion of n-dimensional geometry in the first half of the 19th century, and then proceeds to a detailed discussion of Riemann's contributions, those of Beltrami, Helmholtz, Klein, connections with the foundations of geometry, topology of surfaces, complex function theory, Poincaré's work on the topology of higher dimensional spaces, and the connections with the history of "Mannigfaltigkeiten" and modern mathematics. Three appendixes discuss connections with automorphic functions, birational geometry of algebraic structures and Poincaré's study of the second Betti number of algebraic surfaces. Bibliography, but *no* index.

3063. Scott, J. F. *The Scientific Work of René Descartes (1596–1650).* London: Taylor and Francis, 1952, vii + 211 pp. Reprinted 1976.New York: Garland, 1987.

Discusses *Discours de La Méthode, La Dioptrique, Les Météores*, and the *Principia Philosophiae*, but the bulk of the book is an analysis of the contents of *La Géométrie*. See also item 2127.

3064. Staeckel, P. "Gauss als Geometer". In *Materialien für eine Wissenschaftliche Biographie von Gauss.* Edited by F. Klein, M. Brendel, and L. Schlesinger. *Nachrichten der K. Gesellschaft der Wissenschaften zu Göttingen, mathem.-physik. Klasse* 5 (1917). Reprinted in C. F. Gauss, *Werke* 10 (2) (4), Göttingen: Gesellschaft der Wissenschaften, 1922–1933, 1–123.

Chapters on Gauss's work in foundations of geometry, geometry of position, complex numbers and their relation to geometry, elementary and analytic geometry, and the general theory of surface curvature. Includes a bibliography of his work in these areas.

3065. Struik, Dirk J. "Outline of a History of Differential Geometry". *Isis* 19 (1933), 92–120; 20 (1933), 161–191.

Briefly discusses pre-Leibnizian contributions, the work of Euler, Clairaut, Monge and his school, Gauss, the French school of the 1840s, Riemann, Italian contributions, modern developments, sources, and external influences.

3066. Taton, René. *L'oeuvre scientifique de Monge.* Paris: Presses Universitaires de France, 1951, 441 pp.

A brief biography followed by a discussion of Monge's work in descriptive geometry, analytic and differential geometry, and as a precursor of modern geometry, mathematical analysis, and other scientific areas. See also items 2277, 2328.

3067. Taton, René. *L'oeuvre mathématique de G. Desargues.* Paris: Presses Universitaires de France, 1951, 232 pp. Second edition, Paris: J. Vrin;

Lyon: Institut interdisciplinaire d'études epistemologiques, 1988, viii + 238 pp.

Examines Desargues's life and work and its significance. The centerpiece is the text of Desargues's "Brouillon Project." Letters to Mersenne and from Descartes and Beaugrand are included, along with a bibliography of Desargues's work. See also item 2120.

3068. Toepell, Michael-Markus. *Über die Entstehung von David Hilberts "Grundlagen der Geometrie".* (Studien zur Wissenschafts-, Sozial- und Bildungsgeschichte der Mathematik, 2). Göttingen: Vandenhoeck & Ruprecht, 1986.

The background and influence of David Hilbert's *Foundations of Geometry.*

3069. Torretti, R. *Philosophy of Geometry from Riemann to Poincaré.* Dordrecht: Reidel, 1978, xiii + 459 pp.

Despite its title, 250 of its 459 pages are devoted to a chiefly historical account of non-Euclidean geometries, including the development of manifolds (following Gauss and Riemann), projective geometry (up to Klein), the Helmholtz-Lie space problem, and axiomatics (Pasch, Peano, and Hilbert). See also items 3062, 4165.

3070. Ziegler, Renatus. *Die Geschichte der geometrischen Mechanik im 19. Jahrhundert. Eine historisch-systematische Untersuchung von Möbius und Plücker bis zu Klein und Lindemann.* (Boethius: Texte und Abhandlungen zur Geschichte der Exakten Wissenschaften, XIII). Wiesbaden: Franz Steiner Verlag, 1985. vii + 260 pp.

On the history of geometrical mechanics in the 19th century, from Plücker and Möbius to Felix Klein and Lindemann.

Non-Euclidean Geometry

3071. Bonola, R. *Non-Euclidean Geometry. A Critical and Historical Study of Its Development.* Translated by H. S. Carslaw. New York: Dover, 1955.

Originally published in German (Berlin: Teubner, 1908; 2nd ed. 1919, 1921).Includes translations by G. B. Halsted of J. Bolyai's *The Science of Absolute Space* (1832), and N. I. Lobachevskii's *Geometrical Researches on the Theory of Parallels* (1840). Bonola's account is still the classic history. It surveys Greek, Moslem, and Western attempts to analyze Euclid's parallel postulate, gives a very thorough account of the work of Schweikart, Taurinus, and Gauss, as well as the successful discoveries of Bolyai and Lobachevskii; it is based on the works of F. Engel and Stäckel.

3072. Dou, A. M. "Logical and Historical Remarks on Saccheri's Geometry". *Notre Dame Journal of Symbolic Logic* 11 (1970), 385–415.

Discusses Saccheri's *Euclides ab omni maevo vindicatus* (1733), in which he attempts to prove Euclid's fifth postulate (on parallels). It is now known that Saccheri's axioms may lead to elliptic and hyperbolic as well as Euclidean geometries. The author gives a commentary on Saccheri's methods, and shows their influence on Lambert, Gauss, Bolyai, and Lobachevsky.

3073. Engel, F., and P. Staeckel. *Die Theorie der Parallellinean von Euklid bis auf Gauss.* Leipzig: Teubner, 1895. 2 vols.

Despite the title, the book passes from Euclid to Wallis with no mention of intermediate developments. Prime focus is on the work of Saccheri, Lambert, Gauss, Schweikart, and Taurinus.

3074. Engel, F., and P. Staeckel. *Urkunden zur Geschichte der nichteuklidische Geometrie.* Leipzig: Teubner, 1899–1913. 2 vols. Reprinted New York and London: Johnson Reprint Corporation, 1972.

Volume 1 concerns Lobachevsky; volume 2, Wolfgang Bolyai and Johann Bolyai. Each volume includes a frontispiece, the first portraying Lobachevsky, the second, Bolyai. Engel edited volume 1, which provides German translations of two geometric treatises originally written in Russian (235 pp.). Engel then offers detailed notes (pp. 237–344), followed by a lengthy study of Lobachevsky's life and works (pp. 349–445), along with a bibliography and indexes. Volume 2 was edited by Stäckel. It begins with a lengthy, detailed biographical and critical history of the Bolyai family, Wolfgang's work as a professor of mathematics, his son Johann's discovery of "absolute geometry", imaginary numbers, connections with Lobachevsky's works, the theory of parallel lines, etc. The rest of volume 2 provides German translations of selected portions of the writings of both Bolyais.

3075. Gray, J. J. *Ideas of Space.* Oxford: Clarendon Press, 1979. 2nd ed. Oxford: Clarendon Press; New York: Oxford University Press, 1989,xi + 242 pp.

Gray argues more strongly than Bonola for the crucial role of mathematical methods (trigonometry, differential geometry) in making the discovery of non-Euclidean geometries possible, and less for questions in logical consistency. Kline, item 2300, especially Chapters 36 and 38, stresses the importance of the physical implications, emphasized by Bolyai and Lobachevskii.

3076. Gray, J. J., and L. Tilling. "Johann Heinrich Lambert, Mathematician and Scientist, 1728–1777". *Historia Mathematica* 6 (1979), 236–258.

3077. Hawkins, Thomas. "Non-Euclidean Geometry and Weierstrassian Mathematics: The Background to Killing's Work on Lie Algebras". *Historia Mathematica* 7 (1980), 289–342.

See item 2502.

3078. Henderson, Linda Dalrymple. *The Fourth Dimension and Non-Euclidean Geometry* Princeton: Princeton University Press, 1983, xxiii + 453 pp.

This book discusses the influence of non-Euclidean geometry on various movements in art around the turn of the twentieth century.

3079. Kagan, V. *Lobachevsky and His Contribution to Science.* Moscow: Foreign Languages Publishing House, 1957.

Brief (91-page) general appreciation of Lobachevsky, with illustrations, in the series "Men of Russian Science." Shortened translation of *Lobachevskii i ego mesto v nauke* (Moscow, 1955, 301 pp.).For a biographical appreciation of Kagan, see A. M. Lopshits and P. K. Rashevskii, "Veniamin Fedorovich Kagan (1869–1953)", *Zamechatel′nye uchenye Moskovskogo Universiteta* 39 (1969), 42 pp., with portrait.

3080. Rosenfeld, B. A. *A History of non-Euclidean Geometry.* Translated from the Russian by Abe Shenitzer. New York: Springer, 1988. xii + 471 pp.

This comprehensive history begins with "On the rotating sphere" by Autolycus, about 300 B.C., and covers such topics as W. Pauli's use of indefinite bilinear forms to define length in Hilbert space, biquasisimple algebras and H. Freudenthal's magic square of sixteen geometries, Kepler's invention of a "point at infinity", G. Desargues's use of "involution", hyperbolic geometry, multidimensional spaces (C. G. J. Jacobi, A. Cayley, H. Grassmann and L. Schlafli), curvature of space (general theory of relativity, fibrations, exterior forms and Betti numbers), groups of transformations (Galois theory, Klein's quadric in 5-space representing the lines of 3-space, Coxeter diagrams for reflection groups, Dynkin diagrams and Sataki diagrams for simple Lie groups and their geometric interpretation by C. Ehresmann and J. Tits), applications of algebras. A detailed review with further references is given by H. S. M. Coxeter in **MR** 89k:01001.

3081. Sommerville, D. M. Y. *Bibliography of Non-Euclidean Geometry.* London: Harrison & Sons, 1911. Reprinted New York: Chelsea, 1970.

Interprets its brief generously, lists articles chronologically, with an indication of the subject matter.

3082. Stillwell, John. *Sources of Hyperbolic Geometry.* (History of Mathematics, 10.) Providence, R.I.: American Mathematical Society; London: London Mathematical Society, 1996. x + 153 pp.

English translations of E. Beltrami's "Saggio di interpretazione della geometria non-euclidea" (*Giornale Matemat.* 6 (1868), 284–312) and "Teoria fondamentale degli spazii di curvatura constante" (*Ann. Mat. Ser. II* 2 (1868–69), 232–255), F. Klein's "Über die sogenannte nicht-euklidische Geometrie" (*Math. Ann.* 4 (1871), 573–625), and three papers by H. Poincaré on applications of non-Euclidean geometry (*Acta Math.* 1 (1882), 1–62; *Acta Math.* 3 (1883), 49–92; *Assoc. Franc. Compt. Rend.* (1881), 132–138). The translations are preceded by short historical introductions. Victor V. Pambuccian in **MR** 97k:01071 corrects some misleading statements in these introductions.

LOGIC AND SET THEORY

This section covers logic from ancient to modern times, although it excludes from its lists survey articles on very recent developments in a given area. In addition, literature concerned with the philosophy of logic is cited only if it has a noticeably historical character. The term "logic" has been interpreted historically to refer to whatever bodies of knowledge were regarded as "logical" at the time; but choice has been exercised so as to concentrate on works which deal with the bearing of "logic" on mathematics.

The history of set theory can be traced back to antiquity, insofar as the problem of continuity and infinity are related to the subject generally. The bibliography given here, however, limits itself with but few exceptions to the most modern development of set theory, beginning with the pioneering researches of Georg Cantor in the 1870s. Readers are referred to other sections of this bibliography for allied literature, especially the sections on analysis, on number (where theories of the real numbers are treated), and on topology, which has an obvious bearing on the history of set theory.

General Histories

3083. Bocheński, I. M. *A History of Formal Logic.* Notre Dame, Ind.: University of Notre Dame Press, 1961, xxii + 567 pp. A revised translation of the German original, *Formale Logik.* Freiburg, Munich: Verlag Karl Alber, 1956. Reprinted New York: Chelsea, 1970.

Mainly a selection of quotations from primary sources (all periods). Not a source from which to *learn* the history of logic, but useful passages and extensive bibliography. Divides logic into four varieties: Greek, Scholastic, Mathematical (one-third of text), and Indian. It consists of short texts, in English, and a minimum of connective commentary. Requires some sophistication in logic. Complements Kneale, item 3086, nicely, but both essentially end with *Principia Mathematica* (1910–1913). Contains an extensive bibliography.

3084. Dumitriu, A. *History of Logic.* Tunbridge Wells: Abacus, 1977. 4 vols.

Rather breathless scamper over all periods, and also a wide range of applications of logic.

3085. Jørgenson, J. *A Treatise of Formal Logic.* Copenhagen, London: Levin and Munksgaard, 1931. Reprinted New York: Russell and Russell, 1962. 3 vols.

Has some historical information, though not impressive over all.

3086. Kneale, William, and Martha Kneale. *The Development of Logic.* Oxford: Clarendon Press, 1962, viii + 762 pp.

The most complete and best survey of the history of logic from the Greeks to the early years of this century. Half of the book deals with the nineteenth century. It does treat set theory and the foundations of mathematics, and is quite readable by those with very little knowledge of logic.

3087. Prantl, C. *Geschichte der Logik in Abendlände.* Leipzig: S. Hirzel, 1855–1870. Reprinted Leipzig: G. Fock, 1927; Graz: Akademische Druck- und Verlagsanstalt, 1955. 4 vols.

Of interest for the extraordinary *history of* the history of logic, where the decline of logic in the late Renaissance left Prantl knowing absolutely *less* logic than did some of his primary figures.

3088. Prior, A. N., et al. "Logic, History of". *The Encyclopedia of Philosophy.* Vol. 4. Edited by Paul Edwards. New York: Macmillan, 1967, 513–571.

A good introduction to the whole of the history of logic.

3089. Scholz, H. *Geschichte der Logik.* Berlin: Junker und Dünnhaupt, 1931. English translation, *Concise History of Logic*, by K. F. Leidecker. New York: Philosophical Library, 1961.

3090. Ueberweg, F. *System der Logik und Geschichte der logischen Lehren.* Bonn, 1857, and later editions.

Encyclopaedias and Source Books

3091. Audi, R., ed. *The Cambridge Dictionary of Philosophy.* Cambridge: Cambridge University Press, 1995.

Reasonable coverage of logicians, a little slight on topics; short articles, no bibliographies.

3092. Brown, S., D. Collinson, and R. Wilkinson, eds. *Biographical Dictionary of Twentieth-century Philosophers.* London: Routledge, 1996.

Moderate coverage of logicians; articles have bibliographies.

3093. Burkhardt, Hans, and Barry Smith, eds. *Handbook of Metaphysics and Ontology.* Munich: Philosophia, 1991. 2 vols.

Useful coverage of topics and figures often omitted elsewhere; articles have bibliographies.

3094. Davis, Martin. *The Undecidable. Basic Papers on Undecidable Propositions, Unsolvable Problems and Computable Functions.* Hewlett, N.Y.: Raven Press, 1965, vi + 440 pp.

An anthology of seminal papers on recursion theory by Gödel, Church, Turing, Rosser, Kleene, and Post.

3095. Ewald, William B., ed. *From Kant to Hilbert. A Source Book in the Foundations of Mathematics.* Oxford: Clarendon Press, 1996. 2 vols.

Mixture of texts already well reprinted and/or translated, and little-known pieces. Conceived in part as a complement to van Heijenoort, item 3097.

3096. Grattan-Guinness, I., ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* London: Routledge, 1994. 2 vols.

Part 5 on logic and the foundations of mathematics, both history and philosophy; some relevant articles in other parts.

3097. Van Heijenoort, Jean. *From Frege to Gödel. A Source Book in Mathematical Logic, 1879–1931.* Cambridge, Mass.: Harvard University Press, 1967, xi + 660 pp.

A source book par excellence. English versions of the most important papers of mathematical logic up to and including Gödel's work, with excellent introductions by the editor. See also item 4167.

3098. Vega Reñon, Luis. *Una guía de historia de la Lógica.* Madrid: Universidad Nacional de Educació a Distancia, 1996.

For students and beginners, sketched histories of various periods, together with extensive bibliographies, some are items annotated. An English version would be desirable.

Journals

Some philosophy journals take articles in the history and philosophy of logic or mathematics fairly regularly; see especially *Noûs*, *Philosophia Mathematica* and *Synthese*. Literature is abstracted and reviewed in *The Philosopher's Index*. Specialist journals:

3099. *History and Philosophy of Logic.* London: Taylor & Francis, 1980-.

3100. *Modern Logic.* Ames, Iowa, USA: Modern Logic Publications, 1991-.

Bibliographies

3101. Church, Alonzo. "A Bibliography of Symbolic Logic". *The Journal of Symbolic Logic* 1 (1936), 121–218. "Additions and Corrections", 3 (1938), 178–212. Reprinted Princeton: Princeton University Press, 1938.

A comprehensive bibliography of symbolic logic for the period 1666–1935. Items of "especial interest or importance" have been indicated with an asterisk, a judgment which has stood the test of time. The "Additions and Corrections" contains a very fine-grained and extensive subject index. Subsequent volumes of the journal have reviewed nearly all publications in, and closely related to, symbolic logic (including set theory, which was excluded from the original bibliography), and listed the remainder. Vol. 26 (1961) is devoted to indices of contributed papers, abstracts, reviews by author, reviews by reviewer, and an extensive index of reviews by subject. Unfortunately, for future historians and current logicians, this comprehensive reviewing policy had to be terminated in 1976 for financial reasons.

3102. Risse, W. *Bibliographia Logica. Verzeichnis der Druckschriften zur Logik mit Angabe ihrer Fundorte.* In 4 volumes: *I. 1472–1800*; *II. 1801–1969*; *III. Verzeichnis der Zeitschriftenartikel zur Logik*; *IV. Verzeichnis der Handschriften zur Logik.* Hildesheim, New York: Georg Olms, 1965-79.

Volume I and II: Organized chronologically, but helped by author and very brief subject indices. Includes a lot of non-logic. Volume III: Classified bibliography of primary literature in logic (and some aspects of the history of logic). Most literature cited is post-World War II. Curiously patchy in coverage, though exhaustive when good. Volume IV: List of logic manuscripts from the 7th to the 18th century. Two main sections, medieval authors and more recent authors, organized alphabetically. Good indices.

Biographies

3103. Brent, Joseph. *Charles Sanders Peirce. A Life.* Bloomington and Indianapolis: Indiana University Press, 1993.

Remarkable work, with fine use of archives. Some summary of the logical work.

3104. Dawson, John W., Jr. *Logical Dilemmas. The Life and Work of Kurt Gödel.* Wellesley, Mass.: A. K. Peters, 1997.

Fine use of archives. Much discussion of the logical work.

3105. Lowe, Victor. *Alfred North Whitehead. The Man and His Work.* Baltimore and London: The Johns Hopkins University Press, 1986, 1990. 2 vols.

Vol.1 has informative chapters on Whitehead's *entrée* via Hermann Grassmann and on the later logicism with Russell.

3106. MacHale, Desmond. *George Boole. His Life and Work.* Dublin: Boole Press, 1985.

Some use of archives. Much discussion of the logical work.

Editions

Among the mathematicians whose editions are listed in Section II those who were significantly interested in logic include Bolzano, Boole, Brouwer, Cantor, Frege, Gentzen, Herbrand, Hilbert, Husserl, Jourdain, Leśniewski, Leibniz, Łukasiewicz, Mostowski, Peano, Peirce, Ramsey, Robinson, Russell, Skolem, Tarski, Turing, Weyl, and Whately.

Ancient, Medieval, and Renaissance

This includes various recent editions or translations of previously little known or unknown texts. See book reviews in the journal *History and Philosophy of Logic*.

3107. Ashworth, Earline Jennifer. *Language and Logic in the Post-Medieval Period*. (Synthèse Historical Library 12.) Dordrecht, Holland; Boston, Mass.: D. Reidel Publishing Company, 1974, 304 pp.

Contains a systematic exposition of doctrines, e.g., supposition, consequences. Concentrates on the survival of medieval doctrines. Modern figures, such as Descartes and Leibniz, are excluded.

3108. Ashworth, Earline Jennifer. *The Tradition of Medieval Logic and Speculative Grammar from Anselm to the End of the Seventeenth Century. A Bibliography from 1836 Onwards*. (Subsidia Mediaevalia 9.) Toronto: Pontifical Institute of Mediaeval Studies, 1978, 111 pp.

Concentrates on formal logic and semantics. Modern figures, such as Descartes and Leibniz, are excluded. Helpful indices of names, original texts, texts in translation, subjects.

3109. Boehner, Philotheus. *Medieval Logic. An Outline of Its Development from 1250–c. 1400.* Manchester: Manchester University Press, 1952, 130 pp.

3110. Boehner, Philotheus. *Collected Articles on Ockam*. Edited by Eligius M. Buytaert. St. Bonaventure, New York: The Franciscan Institute, 1958, 482 pp.

3111. Corcoran, J., ed. *Ancient Logic and Its Modern Interpretations*. Dordrecht: Reidel, 1974.

3112. Łukasiewicz, J. *Aristotle's Syllogistic*. 2nd ed. Oxford: Oxford Univresity Press, 1957.

3113. Maierù, Alfonso. *Terminologia logica della tarda scolastica*. Rome: Edizioni dell'Ateneo, 1972, 687 pp.

Exhaustive account of different uses of a small number of terms including *appellatio, copulatio, confusio*, and *propositio modalis*.

3114. Mates, B. *Stoic Logic*. Berkeley, Los Angeles: University of California Press, 1953.

3115. Moody, Ernest Addison. *Truth and Consequence in Mediaeval Logic*. Amsterdam: North-Holland Publishing Company, 1953, 113 pp.

Classic and stimulating account of formal inferences and semantic paradoxes, but to be used with care: based on a limited number of sources, and the use of modern techniques and concepts can be misleading.

3116. Moody, Ernest Addison. "Medieval Logic" under "Logic, History of". *The Encyclopedia of Philosophy*. Vol. 4. Edited by Paul Edwards. New York, London: Macmillan and Free Press, 1967, 528–534.

3117. Pinborg, Jan. *Logik und Semantik im Mittelalter. Ein Ueberblick*. Stuttgart, Bad Cannstatt: Friedrich Frommann Verlag—Günther Holzboog KG, 1972, 216 pp.

Not so much a history as a brief look at a series of authors and themes. Its only fault is its brevity.

3118. Pinborg, Jan, ed. *The Logic of John Buridan*. (Opuscula Graecolatina; Supplementa Musei Tusculani, Vol. 9.) Copenhagen: Museum Tusculanum, 1976, 165 pp.

A very useful collection of papers, exemplifying recent scholarship in medieval logic.

3119. Rijk, Lambertus Marie de. *Logica Modernorum. A Contribution to the History of Early Terminist Logic*. Vol. 1. *On the Twelfth Century Theories of Fallacy*. Assen: Van Gorcum, 1962, 674 pp. Vol. 2. Parts One and Two. *The Origin and Early Development of the Theory of Supposition*. Assen: Van Gorcum, 1967, 615 pp.; 909 pp.

A monumental compilation of material, particularly valuable for the printing of hitherto unknown texts.

3120. Risse, Wilhelm. *Die Logik der Neuzeit. 1. Band. 1500–1640*. Stuttgart, Bad Cannstatt: Friedrich Frommann Verlag–Günther Holzboog, 1964, 573 pp.; *Die Logik der Neuzeit. 2. Band. 1640–1780*. Stuttgart, Bad Cannstatt: Friedrich Frommann Verlag—Günther Holzboog, 1970, 748 pp.

Organized according to schools of thought. Very scholarly, but marred by author's ignorance of formal logic. See also item 3102.

3121. Schmitt, C., Q. Skinner, E. Kessler, and J. Kraye, eds. *The Cambridge History of Renaissance Philosophy.* Cambridge: Cambridge University Press, 1988.

A magisterial survey.

3122. Spade, Paul Vincent. "Recent Research on Medieval Logic". *Synthèse* 40 (1979), 3–18.

Deals mainly with work published since 1960.

3123. Stump, E. *Dialectic and its Place in the Development of Medieval Logic.* Ithaca: Cornell University Press, 1989.

Reprint of previous papers.

3124. Thomas, Ivo. "Interregnum" under "Logic, History of". *The Encyclopedia of Philosophy.* Vol. 4. Edited by Paul Edwards. New York, London: Macmillan and Free Press, 1967, 534–537.

Useful brief introduction to the period between the Middle Ages and Leibniz.

17th and 18th Centuries

3125. de Condillac, E. *Logique. Logic.* Translated and edited by W. R. Albury. New York: Abaris, 1980.

A translation *en face*; a photoreproduction of the 1798 original, together with an excellent editor's introduction.

3126. Wolters, G. *Basis und Deduktion. Studien zur Entstehung und Bedeutung der Theorie der axiomatischen Methode bei J. H. Lambert (1728–1777).* Berlin: de Gruyter, 1980.

Algebraic Logic

3127. Barone, F. "Peirce e Schröder". *Filosofia* 17 (1966), 181–224.

3128. Boole, M. E. *Collected Works.* London: Daniel, 1931, 4 vols.

Amidst much crankiness, useful and probably authoritative comments on Boole's conception of his logic (see L. M. Laita, "Boolean Algebra and Its Extra-Logical Sources: The Testimony of Mary Everest Boole", *History and Philosophy of Logic* 1 [1980], 37–60).

3129. Grattan-Guinness, Ivor. "Wiener on the Logics of Russell and Schröder". *Annals of Science* 32 (1975), 103–132.

See item 3184.

3130. Hailperin, T. "The Development of Probability Logic from Leibniz to MacColl". *History and Philosophy of Logic* 9 (1988), 131-191.

Pioneer paper on a neglected topic.

3131. Houser, N., D. Roberts, and J. van Evra, eds. *Studies in the Logic of Charles S. Peirce*. Bloomington: Indiana University Press, 1996.

Extensive range of essays.

3132. Merrill, D. *Augustus De Morgan and the Logic of Relations*. Dordrecht: Kluwer, 1990.

Partly historical and partly modernish reconstruction.

3133. Panteki, M. *Relationships between Algebra, Differential Equations and Logic in England: 1800-1860*. London: C. N. A. A., 1992. (Doctoral Dissertation.)

Much new information on Babbage, Herschel, De Morgan and G. Boole.

3134. Peckhaus, V. *Logik, Mathesis Universalis und allgemeine Wissenschaft. Leibniz und die Wiederentdeckung der formalen Logik im 19. Jahrhundert*. Berlin: Akademie-Verlag, 1997.

Emergence of formal (mostly algebraic) logic in Britian and Germany.

3135. Rosado Haddock, G. E. "Edmund Husserls Philosophie der Logik und Mathematik in Lichte der gegenwärtigen Logik und Grundlagenforschung". Dissertation, University of Bonn, 1973.

3136. Smith, B., ed. *Parts and Moments. Studies in Logic and Formal Ontology*. Munich: Philosophia, 1982, 564 pp.

Includes extensive bibliography of post-Boolean developments in part-whole logic.

3137. Smith, G., ed. *The Boole-De Morgan Correspondence 1842–1864*. Oxford: Clarendon Press, 1982, 156 pp.

Mathematical Logic and Set Theory

3138. Ashworth, E. J. "An Early 15th Century Discussion of Infinite Sets". *Notre Dame Journal of Formal Logic* 18 (1977), 232–234.

Discusses the 15th-century figure John Dorp, and claims he was aware of non-denumerably infinite sets.

3139. Borga, M., P. Freguglia, and D. Palladino. *I contributi fondazionali della scuola di Peano*. Milan: Franco Angeli, 1985.

Three good essays, unduly neglected.

3140. Borga, M., and D. Palladino. *Oltre il mito della crisi.* Brescia: La Scuola, 1997.

3141. Bunn, R. "Developments in the Foundations of Mathematics". In *From the Calculus to Set Theory, 1630–1910.* Edited by I. Grattan-Guinness. London: Duckworth, 1980, 220–255.

3142. Bunn, R. "Quantitative Relations between Infinite Sets". *Annals of Science* 34 (1977), 177–191.

Discusses Leibniz, Bolzano, and Cantor, in the context of the general history of the ordering of infinite sets from Aristotle to Cantor. See also item 4060.

3143. Cavaillès, J. *Philosophie mathématique.* Paris: Hermann, 1962.

Although not published until well after the author's death during World War II, this is a thoughtful and informative collection of observations on the history and philosophy of modern set theory. See also item 4062.

3144. Chihara, C. S. *Ontology and the Vicious-Circle Principle.* London, Ithaca, N.Y.: Cornell University Press, 1973.

See item 4063.

3145. Church, Alonzo. *Introduction to Mathematical Logic.* Vol. I. Princeton, N.J.: Princeton University Press, 1956, x + 378 pp.

This highly respected monograph contains numerous insightful historical comments on its main themes: propositional, first, and second order logic. See also item 4065.

3146. Couturat, L. *De l'infini mathématique.* Paris: F. Alcan, 1896. Reprinted Paris: Blanchard, 1973.

A defense of Cantor against his adamant critic and opponent Kronecker on the subject of the infinite in mathematics. This book was widely read at the turn of the century, but is now dated.

3147. Curry, Haskell B. *Foundations of Mathematical Logic.* New York: McGraw-Hill, 1963. Reprinted New York: Dover, 1977, viii + 408 pp.

A high-level textbook with numerous historical remarks.

3148. Dalen, D. van, and A. F. Monna. *Sets and Integration. An Outline of the Development.* Groningen: Wolters-Noordhoff Publishing, 1973.

Part I of this book is devoted to "Set Theory from Cantor to Cohen" and was written by van Dalen; Monna is responsible for Part II: "The Integral from Riemann to Bourbaki," which also takes up relevant aspects of set theory as it relates to theories of integration.

3149. Dauben, Joseph Warren. "C. S. Peirce's Philosophy of Infinite Sets". *Mathematics Magazine* 50 (1977), 123–135.

Compares Peirce's discovery and development of non-denumerability and his theories of infinitesimals and continuity, which arose in the context of logic, with similar interests developed by Cantor and Dedekind in the context of analysis. Stresses comparative differences, especially Cantor's opposition to infinitesimals and Peirce's adamant acceptance and development of same.

3150. Dauben, Joseph Warren. *Georg Cantor, His Mathematics and Philosophy of the Infinite*. Cambridge, Mass.: Harvard University Press, 1979, 361 pp.. Paperback reprint, Princeton, N.J.: Princeton University Press, 1990.

An intellectual biography of Cantor, tracing the origins of set theory from his work on trigonometric series and rigorous definition of the real numbers, through the discovery of non-denumerable sets and the eventual development of transfinite numbers to transfinite arithmetic and the theory of trasinfinite ordinal and cardinal nubmers and order types in general. Considers as well the social and academic context in which Cantor's work was done, as well as theological and psychological aspects of Cantor's interests. With photographs and previously unpublished material. Draws heavily on manuscripts, correspondence, and archival sources. See also item 4070.

3151. de Rouilhan, P. *Russell et le cercle des paradoxes*. Paris: Presses Universitaires de France, 1996.

Interesting insights on (not) solving the paradoxes.

3152. Drake, F. R. *Set Theory: An Introduction to Large Cardinals*. Amsterdam: North Holland, 1974.

Considers models of set theory, trees, reflection principles, all with historical notes. This is an advanced text, summarizing work on large cardinals primarily by Tarski and his students since 1950.

3153. Dugac, Pierre. *Richard Dedekind et les fondements des mathématiques*. Paris: Vrin, 1976.

Provides both a scientific biography of Dedekind, with numerous texts, and 58 appendixes of manuscripts and letters written by Dedekind and others (pp. 143–315). This work argues that Dedekind had a much larger role than is usually appreciated in the origins of set theory. This monograph is Number 24 in the Collection des Travaux de l'Académie international d'histoire des sciences. J. W. Dauben's review (*Isis* 69 (1978), 141–143) corrects some mistakes.

3154. Fraenkel, A., Y. Bar-Hillel, and A. Levy, with D. van Dalen. *Foundations of Set Theory*. 2nd rev. ed. Amsterdam: North Holland, 1973.

The revised edition, like its predecessors, is rich in historical references, although designed primarily as an advanced introduction to the subject. See also item 4085.

3155. Garciadiego, A. R. *Bertrand Russell and the Origins of the Set-Theoretic 'Paradoxes'*. Basel: Birkhäuser, 1992.

Includes various pertinent manuscripts.

3156. Grattan-Guinness, Ivor. "An Unpublished Paper by Georg Cantor: 'Principien einer Theorie der Ordnungstypen. Erste Mittheilung". *Acta Mathematica* 124 (1970), 65–107.

This article provides an extensive introduction to and commentary upon a previously unpublished work by Cantor on the theory of order types. It was set in type and then withdrawn from *Acta Mathematica*, largely because the editor, Mittag-Leffler, regarded the developments in Cantor's paper as being of little utility and so abstruse as to cast doubt on the reputation both of Cantor's nascent set theory, as well as Mittag-Leffler's fledgling journal.

3157. Grattan-Guinness, Ivor. *Dear Russell–Dear Jourdain: A Commentary on Russell's Logic, Based on His Correspondence with Philip Jourdain*. New York: Columbia University Press; London: Duckworth, 1977, vi + 234 pp.

Deals with the period 1902–1919 when Russell was writing *Principia Mathematica* and doing his most important work in logic. Extensive editorial comments connect the excerpts from the letters. Treats Jourdain's obsession with well ordering and his (somewhat disappointing) notes on the *Principia*. A very useful 25-page bibliography is included. See also item 4097.

3158. Guillaume, M. "Axiomatique et logique". In *Abrégé d'histoire des mathématiques 1700–1900*. Vol. 2. Edited by J Dieudonné. Paris: Hermann, 1978, 315–430.

Despite the title of the book, the article has a substantial section on 20th-century mathematical logic.

3159. Hawkins, Thomas. *Lebesgue's Theory of Integration: Its Origins and Development*. Madison: University of Wisconsin Press, 1970. Reprinted New York: Chelsea Publishing Company, 1975.

Extensive discussion of set theory, especially from 1870 to 1900, as a background to Lebesgue's development of integration theory.

3160. Hermes, H. "Zur Geschichte der mathematischen Logik und Grundlagenforschung in den letzten fünfundsiebzig Jahren".

Jahresbericht der Deutschen Mathematiker-Vereinigung 68 (1966), 75–96.

Considers the history of mathematical logic and foundational studies since 1890.

3161. Hintikka, Jaakko, ed. *From Dedekind to Gödel. Essays in the Development of the Foundations of Mathematics.* Dordrecht: Kluwer, 1995.

Several valuable articles on various figures.

3162. Jain, L. C. "Set Theory in Jaina School of Mathematics". *Indian Journal of History of Science* 8 (1973), 1–27.

Discusses Indian mathematics which the author interprets in terms of set theory and related ideas.

3163. Johnson, P. E. *A History of Set Theory.* Boston: Prindle, Weber and Schmidt, 1972.

This book is a revised version of the author's doctoral dissertation, "A History of Cantorian Set Theory," presented to the Peabody College for Teachers in 1968. It includes consideration of Georg Cantor and his pioneering contributions to set theory, developments leading to axiomatic set theory, and a lengthy bibliography. Portraits are included of Cantor, Dedekind, Kronecker, Weierstrass, Kummer, and Russell.

3164. Jourdain, Philip E. B. "The Development of the Theories of Mathematical Logic and the Principles of Mathematics". *Quarterly Journal of Pure and Applied Mathematics* 41 (1910), 324–352; 43 (1912), 219–314; 44 (1913), 113–128.

Includes annotations from logicians to whom Jourdain submitted his manuscript on their work for comments.

3165. Mangione, Corrado, and Silvio Bozzi. *Storia de logica da Boole ai nostri giorni.* Milan: Garzanti, 1993.

Extensive treatment up to the 1960s.

3166. Manheim, Jerome H. *The Genesis of Point Set Topology.* Oxford: Pergamon Press, New York: Macmillan, 1964.

Much of the discussion deals with set theory insofar as it relates to topology.

3167. Medvedev, F. A. *Razvitie teorii mnozhestv v deviatnadtsatom veke.* Moscow: Nauka, 1965.

A general, detailed study of the history of set theory in the 19th century, drawing entirely upon published sources.

3168. Moore, Gregory H. *Zermelo's Axiom of Choice: Its Origins, Development, and Influence.* (Studies in the History of Mathematics and the Physical Sciences 8.) New York: Springer, 1982. xiv + 410 pp.

A full-length historical study of the Axiom of Choice and its role in twentieth-century mathematics. The first chapter treats the prehistory of the axiom, particularly the use of arbitrary choices in analysis and the pivotal role of Cantor. The second chapter analyzes the controversy provoked by Zermelo's proof of Cantor's conjecture that every set can be well-ordered. In response to this controversy, Zermelo axiomatized set theory and embedded his proof of the Well-Ordering Theorem within it. The third chapter deals with this axiomatization, together with applications of the axiom in algebra and analysis. The fourth and final chapter details the growing use of the axiom and of its equivalents (such as Zorn's Lemma) in diverse fields of mathematics, as well as the results of K. Gödel on the consistency of the axiom. A brief epilogue discusses developments since 1940.

3169. Pulkkinen, J. *The Threat of Logical Mathematism.* Frankfurt/Main: Lang, 1994.

3170. Quine, W. V. O. *Set Theory and Its Logic.* 2nd ed. Cambridge, Mass.: Harvard University Press, 1969, xiv + 361 pp.

Useful footnotes and remarks on the bearing of logic on the axiomatizations of set theory.

3171. Rodriguez-Consuegra, F. A. *The Mathematical Philosophy of Bertrand Russell: Origins and Development.* Basel: Birkhäuser, 1991.

Innovative philosophical survey, emphasising the role of G. Peano.

3172. Sebestik, Jan. *Logique et mathématique chez Bernard Bolzano.* Paris: Vrin, 1992.

Good general introduction and survey.

3173. Stadler, Friedrich. *Studien zum Wiener Kreis. Ursprung, Entwicklung und Wirkung des Logischen Empirismus im Kontext.* Frankfurt am Main: Suhrkamp, 1997.

Valuable bibliographies of all members and main external figures. and relevant manuscripts.

3174. *Theoria* 12 no. 128 (1997), 200 pp.

Special issue on the history of symbolic logics around 1900.

3175. Thiel, C. *Sinn und Bedeutung in der Logik Gottlob Freges.* Meisenheim am Glan: Hain, 1965. English translation, *Sense and Reference in Frege's Logic.* Dordrecht: Reidel, 1968, ix + 172 pp.

3176. Woleński, J. *Logic and philosophy in the Lvov-Warsaw School.* Dordrecht: Kluwer, 1988.

Best general survey not in Polish.

Formalism and Intuitionism

3177. Detlefsen, M. *Hilbert's Program.* Dordrecht: Reidel, 1986.

Important historico-philosophical consideration.

3178. Peckhaus, V. *Hilbertprogramm und Kritische Philosophie. Das Göttinger Modell interdisziplinärer Zusammenarbeit zwischen Mathematik und Philosophie.* Göttingen: Vandenhoeck und Ruprecht, 1990.

Fine survey of Hilbert's first period in proof theory.

3179. Toepell, M.-M. *Über die Entstehung von David Hilberts 'Grundlagen der Geometrie'.* Göttingen: Vandenhoeck und Ruprecht, 1986.

Study of a surprisingly long background in the 1890s, based on manuscripts.

3180. Van Stigt, W. P. *Brouwers's Intuitionism.* Amsterdam: North-Holland, 1990.

Survey of the work.

3181. Webb, J. *Mechanism, Mentalism, and Metamathematics.* Dordrecht: Reidel, 1980.

Philosophical reflection on recursion, well informed by historical examination of Hilbert's second phase.

20th-Century Logic (General)

3182. Chang, C. C. "Model Theory 1945–1971". *Proceedings of the Tarski Symposium.* Edited by Leon Henkin et al. (Proceedings of Symposia in Pure Mathematics, Vol. 25.) Providence, R.I.: American Mathematical Society, 1974, 173–186.

Presents a diagram of the main areas of research in model theory and a diagram of those topics which influenced later work.

3183. Goldfarb, W. "Logic in the Twenties: The Interpretation of the Quantifier". *Journal of Symbolic Logic* 44 (1979), 351–368.

3184. Grattan-Guinness, Ivor. "Wiener on the Logics of Russell and Schröder...". *Annals of Science* 32 (1975), 103–132.

Describes Wiener's doctoral dissertation (done at Harvard), comparing Russell's logical system in *Principia Mathematica* with Schröder's in *Algebra der Logik.* Discusses Russell's later comments on the thesis, together with Wiener's rejoinders.

3185. Grattan-Guinness, Ivor. "On the Development of Logics Between the Two World Wars". *American Mathematical Monthly* 88 (1981), 495–509.

Covers not only the principal philosophies of mathematics but also first- versus higher-order logics and the status of infinitary logics, recursion and computability, non-classical logics, Polish contributions to logic, and the profession of logic.

3186. Kleene, Stephen C. "The Work of Kurt Gödel". *The Journal of Symbolic Logic* 41 (1976), 761–778.

A high level, but quite understandable, summary and evaluation of the work of Kurt Gödel (1906–1978), undoubtedly the most important logician of the twentieth century. For additional biographical information as well as a list of Gödel's 25 publications, see Hao Wang, "Kurt Gödel's Intellectual Development", *The Mathematical Intelligencer* 1 (1978) 182–185.

3187. Mangione, C. "La logica del ventesimo secolo". In *Storia del pensiero filosofico e scientifico*. Edited by L. Geymonat. Milan: Garzanti, Vol. 6, 1972, 469–682; Vol. 7, 1976, 299–433.

3188. Moore, G. H. "Beyond First Order Logic: The Historical Interplay between Mathematical Logic and Axiomatic Set Theory". *History and Philosophy of Logic* 1 (1980), 95–137.

This essay analyzes the historical relationship between mathematical logic and set theory during the period 1870–1930. It argues that set theory influenced Schröder, Löwenheim, and Hilbert to employ logics with infinitely long expressions. The question whether a logic stronger than first-order was needed for set theory culminated around 1930 in a debate between Zermelo and Gödel over the nature of proof. An appendix contains unpublished writings by Zermelo on the foundations of mathematics.

3189. Mostowski, Andrzej. *Thirty Years of Foundational Studies. Lectures on the Development of Mathematical Logic and the Study of the Foundations of Mathematics in 1930–1964*. Helsinki: Acta Philosophica Fennica, no. 17, 1965; New York: Barnes and Noble, 1966, 180 pp.

These 16 lectures on the development of mathematical logic and the foundations of mathematics from 1930 to 1964 are expository but technical. They concern intuitionistic logic, Gödel's Incompleteness Theorem, Tarski's researches on semantics, Herbrand's and Gentzen's results in proof theory, the theory of models in first-order and higher-order languages, and the foundations of set theory (especially constructible sets and forcing). An excellent bibliography is appended.

3190. Murata, T. "L'évolution des principes philosophico-mathématiques de la théorie des ensembles chez Georg Cantor et leur diffusion en France jusqu'en 1905". Dissertation, University of Paris, 1974.

The author studies the reception and development of the mathematical-philosophical aspects of Georg Cantor's set theory in France during the late 19th century, finishing with the use Lebesgue and others were making of Cantor's ideas in the first decade of this century.

3191. Schoenflies, A. *Entwickelung der Mengenlehre.* Leipzig: Teubner, 1900. 2nd ed., 1913.

Still a useful introduction to the subject. Particularly strong on developments at the turn of the century.

3192. Schoenflies, A. "Die Krisis in Cantor's mathematischem Schaffen". *Acta Mathematica* 50 (1927), 1–23.

An important study of Cantor's first major nervous breakdown, attributed in part to difficulties with Kronecker's opposition to transfinite set theory and to Cantor's own difficulties with solution of the Continuum Hypothesis. Replete with previously unpublished correspondence.

3193. Steiner, H. G. "Mengenlehre". In *Historisches Wörterbuch der Philosophie. Vol. 5.* Basel, Stuttgart: Schwabe, 1981.

Extensive article on the basic concepts and history of set theory with detailed bibliographic notes.

3194. Ulam, S. M. "Infinities". In *The Heritage of Copernicus.* Edited by J. Neyman. Cambridge, Mass.: MIT Press, 1974, 378–393.

Considers Cantor, Gödel, and the problem of infinity, as well as set theory, undecidability, and notation. Ulam asserts that revolutions do occur in mathematics, and that the subject of infinities provides an example.

3195. Vaught, R. L. "Model Theory before 1945". *Proceedings of the Tarski Symposium.* (Proceedings of Symposia in Pure Mathematics, Vol. 25.) Edited by Leon Henkin et al. Providence, R.I.: American Mathematical Society, 1974, 153–172.

Model theory here refers to the study of the relationships between sets of sentences in a formal language and the structures which satisfy them. This is a careful treatment of the history of the deepest results in model theory: the Löwenheim-Skolem theorem, Gödel's completeness theorem for first-order logic, and the seminal work of Tarski, especially his definition of truth. A bibliography of original papers is appended.

Polish Logic

3196. Jordan, Zbigniew A. "The Development of Mathematical Logic in Poland between the Two Wars". In *Polish Logic 1920–1939. Papers by*

Ajdukiewicz, Chwistek, Jaśkowski, Jordan, Leśniewski, Łukasiewicz, Słupecki, Sobociński, and Wajsberg. Oxford: Clarendon Press, 1967, 346–397.

Poland's significant contributions to logic, some of which are published here in English for the first time, are outlined in this essay which was first published in 1944.

3197. MacCall, S., ed. *Polish Logic 1920–1939.* Oxford: Clarendon Press, 1967.

Selection of some Polish writings. See Review by Pogorzelski, W. A. in *Journal of Symbolic Logic* 35 (1970), 442–446.

3198. Rickey, V. F. *An Annotated Leśniewski Bibliography.* Bowling Green: Bowling Green State University, 1972. Supplement 1976.

Logic in Russia and the Soviet Union

3199. Anellis, Irving H. "Mathematical Logic in the Soviet Union, 1917–1980". *History and Philosophy of Logic* 8 (1987), 71–76.

3200. Anellis, Irving H. "Theology Against Logic: The Origins of Logic in Old Russia" *History and Philosophy of Logic*, 13 (1992), 15–42.

Sketch of the history of logic in Russia from the fifteenth century to the mid-18th century, with particular emphasis on the late 17th to early 18th century, presented within the context of the general social and intellectual currents of Russian history of the period.

3201. Bazhanov, Valentin Aleksandrovich. *Nikolai Aleksandrovich Vasil'ev, 1880–1940.* Moscow: Nauka, 1988, 144 pp.

Biography and discussion of the work in logic of philosopher and logician Nikolai Aleksandrovich Vasil'ev as the founder of paraconsistent logic.

3202. Cavaliere, Fania *La logica formale in Unione Sovietica. Gli anni del dibattito, 1946–1965*, Firenze: La Nuova Italia Editrice 1990.

An extensive and detailed historical study of the vicissitudes which formal logic went through at the hands of the dialectical philosophers in the USSR.

3203. Küng, Guido. "Bibliography of Soviet Work in the Field of Mathematical Logic and the Foundations of Mathematics, from 1917 to 1957", *Notre Dame Journal of Formal Logic*, 3 (1962), 1–40.

This bibliography is heavily based upon the bibliographies in Yanovskaya's 1948 and 1959 surveys of Soviet work in mathematical logic, items 3207 and 3208.

3204. Mints, Grigorei Efroimovich "Proof theory in the USSR 1925–1969", *Journal of Symbolic Logic* 56 (1991), 385–424. Reviewed by Anellis, Irving H., *Modern Logic* 4 (1994), 220–226.

3206. Nikitina, P. I., editor. *Ocherki po istorii logiki v Rossii.* Moscow: Izdatel'stvo Moskovskogo Universiteta, 1962. .

A collection of essays on various aspects of the history of logic in Russia and concepts of logic of Russian philosophers, ranging from Aleksandr Radishchev in the mid-18th century to the work of Nikolai Vasil'ev in the period just prior to the First World War. Many of the individual articles are listed separately.

3207. Yanovskaya, Sof'ya A. "Osnovaniya matematiki i matematicheskaya logika". In A. G. Kurosh, A. I. Markushevich, and P. V. Rashevskii, *Matematiki v SSSR za tridtsat let, 1917–1947*, Moscow & Leningrad, GITTL, 1948. 9–50.

Detailed survey of Soviet work in foundations of mathematics and mathematical logic from 1917 to 1947.

Reviewed by Kline, George, *Journal of Symbolic Logic* 16 (1951), 46–48.

3208. Yanovskaya, Sof'ya A. "Matematicheskaya logiki i osnovani matematiki". In *Matematika v SSSR za sorok let, 1917–1957*, 1, Moscow, Fizmatgiz., 1959, 3–120.

Detailed survey of Soviet work in mathematical logic and foundations of mathematics from 1948 to 1957. Reviewed by Cogan, E. J. *Journal of Symbolic Logic* 27 (1962), 470.

Non-Classical Logics

3209. Lewis, C. I. *A Survey of Symbolic Logic.* Berkeley, California: University of California Press, 1918, vi + 406 pp. Reprinted New York: Dover, 1960, xi + 327 pp. (Chapters V and VI omitted).

Valuable for 19th-century logic. Excellent bibliography. See also item 4127.

3210. Rescher, N. *Many-Valued Logic.* New York: McGraw-Hill, 1969.

Contains extensive bibliography.

3211. Rutz, P. *Zweiwertige und mehrwertige Logik. Ein Beitrag zur Geschichte und Einheit der Logik.* Munich: Ehrenwirth, 1973.

Philosophy of Logic

3212. Bowne, G. D. *The Philosophy of Logic 1880–1908.* The Hague: Mouton, 1966.

3213. Haack, S. *Philosophy of Logics.* Cambridge: Cambridge University Press, 1978, xvi + 276 pp.

3214. Rostand, F. *Sur la clarté des démonstrations mathématiques.* Paris: Vrin, 1962, 166 pp.

Fine, little-known study of errors in proofs, including some logical errors.

3215. Ruzavin, G. I. *O prorode matematicheskogo znaniya. . . .* Moscow: Misl′., 1968.

MATHEMATICAL PHYSICS

The name "mathematical physics" can be extended to cover almost all of mathematics and physics, as well as major sections of every other science, such as engineering, biomechanics, geophysics, physical chemistry. This bibliography restricts the term to the following five areas: mechanics, elasticity, fluid dynamics, heat conduction, and sound. To these five has been added a general bibliography of works covering more than one field or works of outstanding importance. Each section has its own introduction.

No attempt has been made at a comprehensive listing here, as the field is too vast; but the choice of histories, texts, and reviews, with a leavening of original sources, has been made so that no major idea or publication will be overlooked after diligent consultation of those actually listed. The five topics are of unequal weight: Fluid Mechanics and Elasticity outweigh the other three since mechanics, heat, and sound form part of these topics.

To most of the sections have been added histories of major mathematical methods used in that topic; for example, differential geometry is used in elasticity theory. Again, some collateral topics have been mingled with each main topic; for example, crystallography has been combined with heat conduction. Further, some national histories have been sprinkled over the six sections, with the location of these histories depending on which of the topics features in the history.

The period most intensively covered is 1700–1900, with some protrusion at either end. Many original sources have been deliberately though reluctantly omitted in order to keep the bibliography within reasonable bounds; since almost all of the originals are featured in Truesdell's various works, not too much pain will be occasioned by this.

General Studies

Into this section are collected all the general methods of mathematical physics: vector analysis, series, transforms, differential equations, general histories of mathematical physics, and related technology. The mathematical methods concentrated on here are twofold: those for solution of differential equations, with H. F. K. L. Burkhardt on series solutions, Deakin on the Laplace transform solution, Schlissel on asymptotic solutions, and Demidov on general partial differential equations; and those of vector analysis, in the texts of Gibbs and Weatherburn.

There are several histories: Auerbach, Dugas, Grigor′yan, Rosenberger, and Truesdell on mechanics or physics in general, and that of Singer on later 19th-century technology; to these could be added the history by I. Szabó listed under Mechanics. The several texts—Auerbach-Hort, Courant-Hilbert, Flügge, Gibbs-Wilson, Kneser, Thomson and Tait, Weatherburn—are mixed with several general histories of wide ranging topics and a few major sources, such as Green, Helmholtz. While most of these could find homes in the various sections, almost all of them cover three or more sections or are unique of their kind—the articles by H. F. K. L. Burkhardt and Deakin, for example.

Original Works

3216. Abro, A. d'. *The Rise of the New Physics: Its Mathematical and Physical Theories.* New York: Dover, 1951, xi + 1–426 pp. + 24 portraits v + 427–982 pp. + 12 portraits. 2 vols. Originally published as *Decline of Mechanism.* New York: Van Nostrand, 1939.

Volume 1 covers the classical period to circa 1900, while volume 2 deals with the "new" theories of relativity, quantum mechanics, and the associated models. The emphasis is on sketching the physics, with a not-too-heavily mathematical treatment. There are almost no references, and while useful as background, this is not a direct reference for the history of mathematics or physics.

3217. Atiyah, Michael. "Reflections on Geometry and Physics". In *Surveys in Differential Geometry*, No. 2.) Cambridge, MA: International Press, 1993. 1–6.

This article contains some reflections by the distinguished geometer on the recent close interaction between geometry and physics.

3218. Auerbach, Felix. *Entwicklungsgeschichte der modernen Physik, zugleich eine Uebersicht ihrer Tatsachen, Gesetze und Theorien.* Berlin: Springer, 1923, viii + 344 pp.

This is an exposition of physics rather than a history. There are two parts to the book: nine general chapters deal with the development of physics from space, time, matter, and energy through classical mechanics and thermodynamics, then vibrations, wave motion, heat conduction, and radiation through to black-body radiation, quantum mechanics, and relativity. Then seven special chapters deal with individual topics of mathematical physics: rigid bodies, elastic solids, fluids, sound, heat, electormagnetism, and light. The author was at the center of developments in physics that he describes.

3219. Auerbach, Felix, and Wilhelm Hort. *Handbuch der physikalischen und technischen Mechanik.* Leipzig: Johann Ambrosius Barth, 1926–1931. 7 bände.

This is typical of all such handbooks and encyclopedia. The seven volumes run to a thousand or so pages each, and mix engineering, technology, mathematics, and physics, with articles by many different authors. Korn, Nemenyi, Lichtenstein, and others feature in its pages, and the articles are well referenced in their footnotes as well as at their ends.

3220. Bikermann, Jacob Joseph. "Capillarity before Laplace: Clairaut, Segner, Monge, Young". *Archive for History of Exact Sciences* 18 (1978), 103–122; "Theories of Capillary Attraction". *Centaurus* 19 (1975), 182–206.

The first of these articles relates the work of the authors in the title to that of Laplace; it is mainly polemical and about priority, and has 30 references (at the end). The second article covers Mariotte, Laplace, Young, Poisson, Franz Neumann, and Dupré, and chides physicists about the lack of modern experimental work done on the hypotheses of these people; there are 17 references.

3221. Burkhardt, Heinrich Friedrich Karl Ludwig. "Entwicklungen nach oscillirenden Funktionen und Integration der Differentialgleichungen der mathematischen Physik". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 10 (1901–1908), viii + 1804 pp. This was also issued separately in two volumes, Leipzig: B. G. Teubner, 1908, xii + xii + 1800 pp. Reprinted New York: Johnson Reprint Corp., 1960.

This wonderful report with several thousand references, mainly and unfortunately in the 9,000 footnotes, concentrates on analysis rather than mathematical physics, although vibrating bodies and other applications are discussed at length. It covers this field to 1850, with only a small number after this date, and is a report in the tradition of Hilbert, Brill-Noether, and Minkowski in this series. A somewhat condensed version of this review appears in the *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, as two articles, again by Heinrich Burkhardt, "Trigonometrisch Interpolation (Mathematische Behandlung periodischer Naturerscheinungen)," in volume II (A9a), pp. 642–694, and again "Trigonometrische Reihen und Integrale bis etwa 1850," in volume II (A12), pp. 819–1354; see item 2607. The latter review is extended by that of Emil Hilb and Marcel Riesz in Part 3, "Neuere Unterscuhungen über trigonometrische Reihen" (1922), pp. 1189–1228, where the story is taken as far as Riemann; other articles in Part 3 of Volume II give further information on this and related topics. For literature up to 1920, see Maurice Marie Albert Lecat, *Bibliographie des séries trigonométriques, avec un appendice sur le calcul des variations* (Louvain: n.p., 1921, viii + 167 pp.). There is a *Compléments* (Louvain, 1924, 15 pp.). See also item 2888.

3222. Courant, Richard, and David Hilbert. *Methoden der mathematischen Physik. Band I*, Berlin: Springer, 1924; *Methoden der mathematischen Physik. Band II*, 1937. There is an English translation, *Methods of Mathematical Physics*, New York: Interscience, 1953.

A good description of the writing of these volumes is given in Constance Reid's *Courant in Göttingen and New York: The Story of an Improbable Mathematician* (New York: Springer, 1976, pp. 198–199), where Courant's preference for the by-then-dated "classical" approach to integral equations and existence theorems for partial differential equations is indicated. The material and style of these volumes dominated the world stage for a generation, as "the" approach to the solution of linear (second-order) partial differential equations; cf. also M. S. Berger, *Bulletin of the American Mathematical Society, n.s.* 4 (1981), 362–368.

3223. Deakin, Michael A. B. "The Development of the Laplace Transform, 1737–1937. I. Euler to Spitzer, 1737–1880". "The Development of the Laplace Transform, 1737–1937. II. Poincaré to Doetsch, 1880–1937". *Archive for History of Exact Sciences* 25 (1981), 343–390; 26 (1982), 351–381.

These two articles present a thoroughly documented (over 200 references) and balanced picture of the mathematical and engineering history of this important theoretical and practical tool. See also item 2629.

3224. Demidov, Sergei S. "Vozniknovenie teorii differentisial′nykh uravnenii s chastnymi proizvodnymi". (†Origins of the theory of partial differential equations†). *Istoriko-Matematsichekie Issledovaniia* 20 (1975), 204–220.

A short introduction to Euler and d'Alembert on partial derivatives in differential equations, with fifteen references. See also item 2891.

3225. Dugas, René. *Histoire de la mécanique.* Preface de Louis de Broglie. Paris: Dunod; Neuchatel: Griffon, 1950, 649 pp. There is an English translation by J. R. Maddox, *A History of Mechanics.* New York: Central Book Company, 1955, 671 pp.

This major history is a series of accounts of the work of individuals, in five general periods: to the Renaissance; the 17th century, the century of formation; the 18th, century of organization; then Lagrange and after; and finally the 19th to 20th centuries. It is impossible that the treatment on such a scale be fully balanced; see the reviews quoted.

Reviews: Cohen, I. Bernard, *Isis* 42 (1951), 271–272.

Truesdell, Clifford, *Mathematical Reviews* 14 (1953), 341–343.

3226. Duhem, Pierre Maurice Marie. *La théorie physique: son objet et sa structure.* Paris: Chevalier and Rivière, 1906. 2nd ed. as *La théorie physique: son objet—sa structure.* Revue et augmentée. Paris: Rivière, 1914, viii + 514 pp.

This history and philosophy of physics describes the place of mechanical models, mathematical deduction, and experiment in theoretical physics; it argues that the nature of physical laws is such that a whole theory, not just a single law, is falsified or destroyed by experimental evidence to the contrary. See also his *Evolution de la mécanique* (Paris: Joanin, 1903, 348 pp.).

3227. Flügge, S., ed. *Encyclopedia of Physics–Handbuch der Physik. Band III, Teile 1 & 3.* Berlin: Springer, 1960 (Part I); (1965) (Part 3).

This volume deals with mechanics, and the articles of most importance are the following: from Part 1, "The Classical Field Theories", pp. 226–793, by C. Truesdell and R. A. Toupin, and the appendix to this article, "Tensor Fields", pp. 794–858, by J. L. Ericksen. From Part 3, "The Non-Linear Field theories of Mechanics", by C. Truesdell and W. Noll, which occupies all viii + 602 pages of this Part.

With nearly 2,000 references, and an overview of the whole area of mathematical physics, these three give a résumé, with historical foundations, of the geometry, kinematics, balance equations, and response-functions to 1960, as well as the mechanics of fluids, elastic solids, and other more exotic materials to 1965. Thermodynamics and electromagnetism are not neglected. The references to the older literature, back to 1680, complement the three reviews by Truesdell in the *Leonhardi Euleri Opera Omnia* and the *Mechcanical Foundations*, and provide rapid and accurate entry into the literature.

3228. Frankel, Eugene. "Jean-Baptiste Biot: The Career of a Physicist in 19th-Century France". Dissertation, Princeton University, 1972, vii + 404 pp.

This history depicts Biot, Laplace, and Arago in the period 1795–1830. It details some of the research done by Biot and Arago, and argues that science became a profession to be followed, with second-rate workers appearing in some of the roles. It is very good for a general overview of the period and of the force towards the mathematicization of physics under Poisson, Laplace, Biot, Ampère, and others. There are 300 references at the end of the thesis.

3229. Frankel, Eugene. "J.-B. Biot and the Mathematicization of Experimental Physics in Napoleonic France". *Historical Studies in the Physical Sciences* 8 (1977), 33–72.

The period is reviewed for trends in mathematicization rather than details. For details one should consult the work of Ivor Grattan-Guinness, Rod Home, John Clark, and others quoted by them. The 100 or so references lie in the footnotes.

3230. Gibbs, Josiah W., and Edwin Bidwell Wilson. *Vector Analysis: A Text-book for the Use of Students of Mathematics and Physics, Founded upon the Lectures of J. Willard Gibbs.* New York: Charles Scribner's Sons, 1901. 2nd ed. 1909, xviii + 436 pp. Reprinted New York: Dover, 1960.

Geometry, algebra, calculus (both differential and integral), and application of vectors appear in a text devoted solely to vector analysis. There are only three references: to Gibbs's original pamphlet of 1880–1881 (reprinted in *The Scientific Papers of J. Willard Gibbs, Vol. 2*, pp. 17–90), to Heaviside's *Electromagnetic Theory*, and to Föppl's lectures on *Die Maxwell'sche Theorie der Electrizität* (Leipzig and Berlin: B. G. Teubner, 1912). The applications to gravity, electromagnetism, elasticity, relativity, and optics became the standard prescription for texts on vector and tensor calculus by Weatherburn, McConnell, Levi-Civita, and others.

3231. Gillmor, C. Stewart. *Coulomb and the Evolution of Physics and Engineering in 18th-Century France.* Princeton, N.J.: Princeton University Press, 1971, xvii + 328 pp.

With nearly 300 references listed at its end, this book is an invaluable source for the work of Coulomb and others on friction, torsion, electrostatics, and civil engineering in this period. Coulomb was one of the first to use mathematics in manpower planning (he published a description of this work in 1799). As with many other biographies of scientific men, Coulomb's life is here written separately from the report of his work: the force driving him to create is not tied to the creation. The dilemma facing all writers of such biographies is the readership of his work: does the writer aim for a general audience that understands men but not much science, or for the restricted one that has some understanding of both? See also item 2953.

3232. Grattan-Guinness, Ivor. "Mathematical Physics in France, 1800–1840: Knowledge, Activity and Historiography". In *Mathematical Perspectives: Essays on Mathematics and Its Historical Development.* Edited by J. Dauben. New York: Academic Press, 1981, 95–138.

This work covers the whole range of mathematical physics in France: reesarch, education, use, and application, with approximately 100 references listed at the end together with several very informative tables.

3233. Green, George. "On the Laws of Reflexion and Refraction of Light at the Common Surface of Two Non-Crystallized Media". *Transactions of the Cambridge Philosophical Society* 7 (1842), 1–24.

This marvellous piece of what Saint-Venant disparagingly called "pure analysis," contains (1) the Lagrangian approach to mechanics via d'Alembert's principle, (2) expansions in Eulerian homogeneous functions (polynomials), (3) the Cauchy-Green tensor for elastic deformations, (4) infinitesimal Lie-group generators of the isotropic symmetry group, (5) the Stokes elasticity equations via the elastic potential, and all this in eight pages.

3234. Grigor′yan, Ashot Tigranovich, and Iosif Benediktovich Pogrebysskii. *Istoriya mekhaniki. S drevneishikh vremen do kontsa XVIII veka* (†History of mechanics. From earliest times to the end of the 18th century†). Moscow: Nauka, 1971, 300 pp., and *Istoriya mekhaniki. S kontsa XVIII veka do serediny XX veka* (†History of mechanics. From the end of the 18th century to the middle of the 20th†). Moscow: Nauka, 1972, 416 pp.

This history, a sequence of articles by a score of authors, has thousands of references but very little mathematics. The volumes have compressed bibliographies for each topic and an index of persons. The meaning of mechanics extends to all of the usual topics in classical mathematical physics; thus these two volumes are useful as a general guide but are not detailed enough to be the leader in this field.

3235. Harman, P. M. *Wranglers and Physicists. Studies on Cambridge Physics in the Nineteenth Century. Papers from the Conference on Cambridge Mathematical Physics in the Nineteenth Century Held at Cambridge University, Cambridge, March 1984.* Manchester, UK: Manchester University Press, 1985, viii + 261 pp.

The role of mathematical physics at Cambridge and, in particular, the development of dynamics in the work of William Thomson (Lord Kelvin) and James Clerk Maxwell. Dominating the education of physicists was the Mathematical Tripos and its syllabus in what P. M. Harman refers to as "mixed mathematics", which included mechanics, hydrodynamics, astronomy and planetary theory, and physical and geometrical optics. C. Smith examines how mathematics helped to broaden sciences like geology; I. Grattan-Guinness gives an account of the French influences, especially of Lagrange, on Cambridge; O. Knudsen describes W. Thomson's analogic reasoning in mathematical formalism and his demarcation between such reasoning and the direct theory of physical reality.

3236. Kneser, Adolf. *Die Integralgleichungen und ihre Anwendungen in der mathematischen Physik: Vorlesungen an der Universität zu Breslau.* Braunschweig: Friedrich Vieweg, 1911, viii + 243 pp.

Integral equations from Fredholm are applied to heat conduction, vibrations, in one, two, and three dimensions, as well as to the Dirichlet problem. Fifty references are listed at the end. This book completely rewrote this section of mathematical physics before Courant-Hilbert.

3237. Minkowski, Hermann. "Kapillarität". *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen, V. 9.* Leipzig: B. G. Teubner, 1907, 558–613.

This lucid article gives a solid historical and mathematical introduction to capillarity as well as some experimental detail; it provides a mathematical counterweight for the articles by Bikermann. There are about 100 references, mostly in the footnotes.

3238. Rosenberger, Ferdinand. *Die Geschichte der Physik in Grundzügen, mit synchronistischen Tabellen der Mathematik, der Chemie und beschreibenden Naturwissenschaften, sowie der allgemeinen Geschichte.* Braunschweig: Friedrich Vieweg. Band I, 1882, ix + 175 pp. Band II, 1884, vii + 407 pp. Band III, 1887–1890, xiii + 826 pp. Reprinted Hildesheim: Georg Olms, 1965.

This is a general history without much mathematics. The volumes cover, repsectively, the history of physics from earliest times to the Middle Ages; then from 1600 to 1780; and finally the next hundred years to 1880.

3239. Schlissel, Arthur. "The Development of Asymptotic Solutions of Linear Ordinary Differential Equations, 1817–1920". *Archive for History of Exact Sciences* 16 (1976/1977), 307–378.

With 100 references to all the masters, this is the key article on asymptotic methods for differential equations with large parameters. The references relate to applications as well as theory. See also items 2791, 2915.

3240. Schlissel, Arthur. "The Initial Development of the WKB Solutions of Linear Second Order Ordinary Differential Equations and Their Use in the Connection Problem". *Historia Mathematica* 4 (1977), 183–204.

The development of a method for obtaining approximate solutions to ordinary differential equations whose coefficients are not necessarily analytic is sketeched for the period 1840–1930. The method is ascribed to Wentzel, Kramers, and Leon Brillouin, all dealing with quantum theory and wave theory of light, but many ohters contributed from various fields of application: Green (water and light waves), Rayleigh (waves), Gans (light), Stokes (sun spectra), Jeffreys (geology), and these things are indicated in the 40 or so references. See also item 2918.

3241. Singer, Charles Joseph, et al. *A History of Technology. Vol. 5: The Late Nineteenth Century, c. 1850 to c. 1900.* Oxford: Oxford University Press, 1958, xxxviii + 888 pp. + 44 pls.

This volume is good for applications of mathematical solutions to technology and engineering in the period, although it does not itself contain any mathematics.

3242. Smith, Crosbie W. "'Mechanical Philosophy' and the Emergence of Physics in Britian: 1800–1850". *Annals of Science* 33 (1976), 3–29.

The article details the slow mathematicization of physics in Britain, i.e., the transition from observation to theoretical explanation as in Thomson, Rankine, Tait, and Maxwell. The 100 or so references are in the footnotes. The article is descriptive rather than mathematical.

3243. Thomson, Sir William, and Peter Guthrie Tait. *Treatise on Natural Philosophy.* Oxford: At The Clarendon Press, 1867, xxiii + 727 pp. The first and only published volume of a projected four. 2nd ed.

published in two parts, Part 1 in 1879, xvii + 508 pp., and Part 2 in 1883, xxvii + 527 pp.

The British bible of mathematical physics, it was very widely used and translated. Despite this, it was cut to just the "physics" and published as the *Elements of Natural Philosophy* in 1873 and 1879, to suit British students who lacked adequate mathematical background. The book gave the first accessible proof of Stokes's theorem, and was one of the first texts on hydrodynamics and elasticity.

3244. Truesdell, Clifford A. "The Mechanical Foundations of Elasticity and Fluid Dynamics". *Journal of Rational Mechanics and Analysis* 1 (1952), 125–300; with corrections, 2 (1953), 593–616. Reprinted as *Continuum Mechanics I: The Mechanical Foundations of Elasticity and Fluid Dynamics*. New York: Gordon and Breach, 1966, xvi + 218 pp.

This classic article is a general exposition of deformable masses, solids, liquids, and others, as this theory stood in 1949, with emphasis on work just prior to that date. The exposition is firmly based on the original sources, and many of the 600 references are dated prior to 1900; these, together with the detailed author index and the appendices to the 1966 reissue, make this an invaluable source for the history of elasticity and fluid dynamics from 1600 to 1950.

3245. Truesdell, Clifford A. *Essays in the History of Mechanics*. Berlin: Springer Verlag, 1968, x + 384 pp.

Several chapters of this book deal with the history of particle and rigid-body mechanics, as opposed to that of continuum mechanics dealt with elsewhere in the book. It presents the history of the principle of moment of momentum for both types of mechanics, and treats of pre-Cauchy continuum mechanics. The style is lively, the author is an expert on his subject, and one meets the primary sources and their authors.

Review: Brush, S. G., *Isis* 61 (1970), 115–118.

3246. Weatherburn, Charles Ernest. *Advanced Vector Analysis with Application to Mathematical Physics*. London: G. Bell, 1924, xvi + 222 pp.

J. H. Michell and C. E. Weatherburn popularized the use of vector analysis and tensor calculus in Australia as soon as they obtained a copy of Gibbs-Wilson. They attempted to introduce it into British applied mathematics but failed. This book and Weatherburn's *Elementary Vector Analysis* (London: Bell, 1921) became standard texts for much too long a period. True, the work was based on all the good authors: Beltrami, Darboux, Gibbs, Love, Maxwell, and Poincaré; but it was never modernized to the standard of, say, Schouten's *Der Ricci-Kalkül*.

Elasticity

The history of elasticity predates Galileo, but the modern theory may be said to start with him. The histories by Todhunter and Pearson and Truesdell cover the whole of our period, 1660–1960, and can be used as a standard to correct that by Saint-Venant for the period 1750–1850. The major mathematical topics listed here are differential geometry in the histories by Reich, Phillips, and Vincensini, to which could be added René Taton's biography of Gaspard Monge, *L'oeuvre scientifique de Monge* (Paris: Presses Universitaires de France, 1951); and integral theorems, those of Green, Ostrogradski, and Stokes, used both in elasticity and in fluid mechanics as well as in other fields of mathematical physics. See the articles by Katz and Stolze.

The prominent place of differential geometry in this theory is made clear by one of Saint-Venant's appendices and by the treatise from the Cosserat brothers. The text by Schouten given here could be multiplied many times over from the works of Gibbs, Weatherburn, Levi-Civita, and many others indicated in Truesdell's extensive works.

3247. Dahan-Dalmédico, Amy *Mathématisations. Augustin-Louis Cauchy et l'école française*. Paris: Albert Blanchard, 1992. ii + 460 pp.

Augustin-Louis Cauchy and the French school. Though this study centers on the mathematical physics of Augustin-Louis Cauchy, the story is that of the mathematization of a new class of physical phenomena, mainly the theory of elasticity. See the review by Albert C. Lewis in **MR** 94d:01021.

3248. Katz, Victor J. "The History of Stokes' Theorem" *Mathematics Magazine* 52, No. 3 (1979), 146–156.

This incomplete history of Stokes's theorem in the wide, modern sense concentrates on Ostrogradski in particular, and on the "vector" forms of the equations, leading to the modern differential-form statement. The 28 references give a good but only partial introduction to this area; they could be supplemented by the works of Chasles, Liouville, Thomson, Lamé, and Despeyrous, as well as the reviews given under the bibliography on potential theory.

3249. Katz, Victor J. "The History of Differential Forms from Clairaut to Poincaré". *Historia Mathematica* 8 (1981), 161–188.

This concentrates on the work of Clairaut, Ostrogradski, Betti, Poincaré, and Volterra; it omits the work of Euler and Fontaine. Further, the author suppresses all physical arguments and applications as they appera in Clairaut, Thomson, and Stokes in particular. There are 53 references listed at the end.

3250. Love, Augustus Edward Hugh. *A Treatise on the Mathematical Theory of Elasticity*. Cambridge: At the University Press, Volume I in 1892 and

Volume 2 in 1893. Later editions to 1927 had only one volume. Reprinted New York: Dover, 1952, from the fourth edition, xviii + 643 pp.

The reprint text dates from 1906 with revisions to 1926. It predates the revolution in concept and scope that came in the period 1940–1966 with Truesdell, Oldroyd, and Noll. The several hundred references are buried in the footnotes scattered around the text. The major problems in elasticity theory—the several geometries, the nonlinear response of the materials, the problem of expressing the properties of materials by functions or integrals—all of these are mentioned, but in the classical 19th-century way, in notations obscuring the features of the model. The clear notation of Gibbs-Wilson with its vectors and dyadics (linear transformations) was not to penetrate the British fog for another 30 years or more.

3251. Moyer, Donald Franklin. "Continuum Mechanics and Field Theory: Thomson and Maxwell". *Studies in History and Philosophy of Science* 9 (1978), 35–50.

This details the mathematical development of vector fields in these areas with nearly 150 references to Maxwell, Thomson, and others. See also item 2990.

3252. Oravas, Gunhard, and Leslie McLean. "Historical Development of Energetical Principles in Elastomechanics. I: From Heraclitos to Maxwell"; "Historical Development of Energetical Principles in Elastomechanics. II. From Cotterill to Prange". *Applied Mechanics Reviews* 19 (1966), 647–658; 919–933.

The first review covers the period 1640–1860, the second 1860–1930. The references listed at the ends of the articles total about 160 or so. The treatment is uneven and not always accurate: *Poisson* extended Lagrange's idea of the potential to electrostatics and elasticity in 1811–1814, and these papers were read by George Green who named and used the concept. Despite such faults, these articles are welcome antidotes to the surfeit of nonmathematical papers on this topic.

3253. Phillips, Esther R. "Karl M. Peterson: The Earliest Derivation of the Mainardi-Codazzi Equations and the Fundamental Theorem of Surface Theory". *Historia Mathematica* 6 (1979), 137–163.

This article continues the development of an aspect of the history of differential geometry "after" Riemann, i.e., the period 1853–1880. It concentrates on the relations between the coefficients of the first and second fundamental forms for surfaces in three-dimensional space. There are two dozen references. See also item 3059.

3254. Poisson, Siméon-Denis. “Mémoire sur les surfaces élastiques”. *Mémoires de la Classe des Sciences mathématiques et physiques de L'Institut, année 1812, Partie 2* (1816), 167–225.

This article was read on the 1st of August, 1814, while an Académie prize competition on its topic was current, but it was not an entry for the prize. It introduced into the French tradition a molecular hypothesis for forces between particles in elastic solids as well as an elastic potential from which the forces were derived. This form of the potential certainly gave Lagrange's biharmonic equation for the vibrations of the surface; but it opened a Pandora's box of elastic constants, and the resulting confusion and controversy was to ruin French engineering education for fifty years.

3255. Reich, Karin. “Die Geschichte der Differentialgeometrie von Gauss bis Riemann (1828–1868)”. *Archive for History of Exact Sciences* 11 (1973), 273–382.

This is a magnificent history of the second period in *differential* geometry. Marvellous, detailed references (800 at least) are given, as well as an index of authors. One misses the flavor of the originals in that the applications are mainly suppressed, e.g., the heat conduction of Riemann and Lamé, the physical arguments of Thomson and Chasles, the conformal mapping problem of geodesy from Gauss and C. G. J. Jacobi. The result is a wonderful description of the *pure* mathematics in the text of this article with the applications and motivation easily mined from the references.

3256. Saint-Venant, Adhémar Jean Claude Barré de, and Claude Louis Marie Henri Navier. *Résumé des leçons données à l'École des ponts et chaussées sur l'application de la mecanique à l'établissement des constructions et des machines. Première partie contenant les leçons sur la résistance des matériaux et sur l'établissement des constructions en terre, en maçonnerie et en charpente. Première section. De la Résistance des Corps Solides, par Navier. Troisième édition avec des notes et des appendices, par M. Barré de Saint-Venant. Tome premier. Fascicule I.* Paris: Dunod, 1864, i–cccxi pp. (Saint-Venant)+ 1–509 pp. (Navier)+ 510–852 pp. (Saint-Venant)+1 pl.

This is invaluable as both text and history. The Riemann curvature tensor is used in linear approximation in an appendix, a forerunner of modern theories due to Eckart and others. The long historical introduction by Saint-Venant and the controversial fifth appendix (also by Saint-Venant) attest to the persistence of accepted positions rather than to the virtue of research in Paris in 1840–1870. The works of Green, Stokes, and Maxwell come in for severe but unwarranted criticism.

3257. Schouten, Jan Arnoldus. *Der Ricci-Kalkül: eine Einführung in die neueren Methoden und Probleme der mehrdimensionalen*

Differentialgeometrie. Berlin: Springer, 1924. Last reprinted 1978, x + 312 pp.

This often-reprinted work is one of the classic texts in differential geometry of other-than-three dimensional Euclidean space. There are over 200 references to literature up to 1923 collected at the end. This book consolidated the new geometries in all but English-speaking countries and led to wide applications of differential geometry.

3258. Stolze, Charles H. "A History of the Divergence Theorem". *Historia Mathematica* 5 (1978), 437–442.

This brief history discusses the work of Green, Gauss, and Ostrogradski on the original divergence theorem, and of Heaviside and Gibbs on the vector form. The undoubted priority for the surface-volume form of the theorem lies with Ostrogradski; the dozen references are adequate for this end but not for the topic.

3259. Todhunter, Isaac, and Karl Pearson. *A History of the Theory of Elasticity and of the Strength of Materials from Galilei to the Present Time. Volume I, 1639–1850, Galilei to Saint-Venant. Volume II, Parts I and II, Saint-Venant to Lord Kelvin*. Cambridge: At the University Press, Vol. I in 1886, xvi + 924 pp.; Vol. II posthumously for Todhunter in 1893, 726 pp. and 546 + 12 pp.

This history is in the usual Todhunter style: it presents a summary of each article, with little evaluation and no synthesis. It should be used in conjunction with the originals and with other histories, e.g., those of Saint-Venant and Truesdell.

3260. Truesdell, Clifford A. *The Rational Mechanics of Flexible or Elastic Bodies, 1638–1788: Introduction to Leonhardi Euleri Opera omnia, series secunda, Volumina X et XI. Leonhardi Euleri Opera omnia, series secunda, Volumen XI, sectio secunda*. Zurich: Orell Füssli, 1960, 435 pp.

This work (volume 11, part 2, of the second series of Euler's *Opera omnia*) contains long quotations and extensive summaries of the results due to Huygens, Hooke, Leibniz, Mariotte, the Bernoullis, Euler, d'Alembert, Lagrange, and others on vibrating strings and the general properties of elastic bars. Proper credit is given to d'Alembert (1746) as first formulator and solver of the wave equation.

3261. Vincensini, P. "La géométrie différentielle au XIXe siècle (avec quelques réflexions générales sur les mathématiques)". *Scientia* 107 (1972), 617–660. English translation, 661–696.

This is a general review of the whole of the 19th century's differential geometry with 111 references listed at the end.

3262. Vizgin, V. P. "Vzaimosvyaz' fiziki i matematiki v XIX veke" (†The relationship between physics and mathematics in the 19th century†). *Istoriko-Matematicheskie Issledovaniia* 22 (1977), 111–126.

The essence of this article is distilled into four pages of chronological tables for the century, listing dates, authors, physics topics, and mathematics.

Fluid Mechanics

Three major topics fall under this heading: the foundations of fluid mechanics proper: aerodynamics and boundary-layer theory; and hydrology-hydraulics-meteorology. The mathematical method indicated is complex function theory, with Stokes's and the divergence theorem being tied to elasticity.

The major guides to the early (1650–1800) history is the pair of reviews by Truesdell in the *Leonhardi Euleri Opera omnia*, items 3268, 3269, and Neményi's history, item 3276. For the 19th century, the reviews by Stokes, Hicks, Brillouin, and Love are fairly complete. The 20th century saw remarkable developments in high-speed flow, beginning with the work of Prandtl on boundary-layers; these are reported in the reviews by Dryden and Tani, covering the period to 1970. For types of materials other than viscous and non-viscous fluids, the seminar by Markowitz forms an easy introduction to the more formal work done by Truesdell and others.

3263. Beyer, Robert T., ed. *Foundations of High Speed Aerodynamics. Facsimiles of Nineteen Fundamental Studies as They Were Originally Reported in the Scientific Journals.* New York: Dover, 1951, xi + 286 pp.

This covers the period 1870–1950, and has an extensive bibliography compiled by one of the foremost workers in the area at the time, George F. Carrier.

3264. Biswas, Asit K. "Beginning of Quantitative Hydrology". *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers* 94 (1968), 1299–1316.

This article covers the contributions of Perrault, Mariotte, and Halley to experimental quantitative hydraulics and the hydrological cycle. There are 34 references at the end of the article.

3265. Brillouin, Marcel. "Questions d'hydrodynamique". *Annales de la Faculté des Sciences de Toulouse pour les sciences mathématiques et les sciences physiques* 1 (1887), 1–80.

Each article in the early volumes of this new series of these *Annales* was paged separately, and this article was the first of a series of survey articles planned by the new editors. References were collected at the end of the article, a revolution in style for the time. Here on pp. 73–80, we have 160 of them, covering the period 1820–1886 on vortex theory (with wonderful illustrations in the text), on jets and free surfaces before Michell, as well as viscosity. This is undoubtedly the major review of the fluid flow between Stokes (1846) and Love (1901); it betrays no French bias, and deals with viscosity only briefly.

3266. Dryden, Hugh L. "Fifty Years of Boundary-Layer Theory and Experiment". *Science* 121 (1955), 375–380.

This is a brief review of boundary-layer theory from Prandtl's introduction of the concept (1904) to 1954, with 150 references listed at the end of the article.

3267. Durand, William Franck, ed. *Aerodynamic Theory.* Berlin: Springer, 1934–1936. 6 vols. Reprinted New York: Dover, 1963, and bound as 6 vols. in 3.

The twenty sections of this work cover mathematics, fluid mechanics, the history of aeronautics, and the whole of aerodynamics to date of publication. The historical sketch by R. Giacomelli and E. Pistolesi, "Historical Sketch of Aviation Theory", on pp. 305–395 of Volume 1, does not have a complete bibliography but there is a substantial one at the end of Volume 2, with references to other, exhaustive bibliographies; many other sections contain further bibliographies.

3268. Euler, Leonhard. *Leonhardi Euleri Opera omnia, series secunda, Volumen XII. Commentationes mechanicae ad theoriam corporum fluidorum pertinentes, Volumen prius.* Edited by C. Truesdell. Zurich: Orell Füssli, 1954, cxxv + 288 pp.

This volume contains, on pp. vii–cxxv, Truesdell's famous review of *Rational Fluid Mechanics, 1687–1765*, continued below; it features the work of Newton, Huygens, Clairaut, Euler, the Bernoullis, d'Alembert, and Lagrange. Major parts of this review paraphrase or summarize the five foundation papers by Euler which appear on pp. 1–168 in this volume; these papers date from 1755 to 1757. Statements about Johann Bernoulli on pp. xxxii and xxxvii should be read in the light of Truesdell's later comments given in his review of I. Szabó's book: "An Essay Review of *Geschichte der mechanischen Prinzipien und ihrer wichtigsten Anwendungen*", *Centaurus* 23 (1980), 163–175, esp. p. 168.

3269. Euler, Leonhard. *Leonhardi Euleri Opera omnia, series secunda, Volumen XIII. Commentationes mechanicae ad theoriam corporum fluidorum pertinentes. Volumen posterius.* Edited by C. Truesdell. Zurich: Orell Füssli, 1955, cxviii + 375 pp.

This contains an editor's introduction, a review *The Theory of Aerial Sound, 1687–1788*, and the completion of the above review, *Rational Fluid Mechanics, 1765–1788* (see item 3268). The five papers of Euler in this volume cover the period 1768–1777 and deal with equilibrium and motion of fluids, motion of fluids in tubes, and sound tubes.

3270. Frisinger, H. Howard. "Mathematicians in the History of Meteorology: The Pressure-Height Problem from Pascal to Laplace". *Historia Mathematica* 1 (1974), 263–286.

This review covers 17th- and 18th-century beginnings of mathematical meteorology, with a bibliography of 50 fundamental references.

3271. Hicks, William Mitchinson. "Report on Recent Progress in Hydrodynamics. Part I. General Theory". *Report of the Fifty-First Meeting of the British Association for the Advancement of Science, 1881.* London: John Murray, 1882, 57–88.

This review covers the forty years from Stokes's report of 1846, and contains: the general equations of motion as handled by Clebsch, Thomson, and Tait; vortex theory, Helmholtz, Thomson; free surfaces, Helmholtz, Rayleigh, Kirchhoff, Christoffel; motion of bodies through fluids, by most of the above authors as well as Lamb and Bjerknes; viscous fluids, Meyer, Maxwell, Bobylev; waves, Stokes, Boussinesq, Rankine, Reynolds. The many references are given in the footnotes.

3272. Hicks, William Mitchinson. "Report on Recent Progress in Hydrodynamics. Part II. Special Problems". *Report of the Fifty-Second Meeting of the British Association for the Advancement of Science, 1882.* London: John Murray, 1883, 39–70.

This review of special problems continues the previous item and deals with solutions of Laplace's equation under various boundary conditions. The authors of the hundreds of footnoted references are, in the main, those given in the *General Theory* report. The main special problems reviewed are: two-dimensional motions, using the (complex) potential; three-dimensional motions using the potential and the (electro)magnetic analogy; viscous fluids. Solutions for cylinders, spheres, ellipsoids, all moving through fluids, or for fluids moving through pipes and various other configurations, are reviewed.

3273. Lamb, Horace. *Hydrodynamics*. 6th ed. Cambridge: The University Press, 1932, xv + 738 pp. Reprinted many times, including New York: Dover, 1952. The first edition was in 1879, as a *Treatise on the Mathematical Theory of the Motion of Fluids*, with subsequent editions in 1895, 1906, 1916, and 1924.

This text is a classic, much used and often quoted. Its several hundred references are, as usual, interred in the footnotes. Over half of the text is devoted to waves, and there is a chapter on rotating masses of liquid. Despite its being last revised in 1932, this book seems timeless, covering many "modern" topics such as solitary waves, and geophysical and atmospheric flows.

3274. Love, Augustus Edward Hugh. "Hydrodynamik: Physikalische Grundlegung" and "Hydrodynamik: Theoretische Ausführungen". *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer*

Anwendungen, IV.15, and IV.16. Leipzig: B. G. Teubner, 1901, 48–83; 84–147.

These reviews were revised and extended by Love, Paul Appell, H. Bergelin, and H. Villat in the French translation of them, in the *Encyclopédie des sciences mathématiques pures et appliquées, Tome IV, Partie 5* (1912), 61–101 and (1914) 102–208.All these have largely been superseded by Truesdell's *Encyclopedia of Physics* articles, but they do offer concentration on fluid dynamics. As usual, the many hundred references are given in the footnotes.

3275. Markowitz, Herschel. "The Emergence of Rheology". *Physics Today* 21, No. 4 (1968), 23–30.

This review is a good general introduction to rheology and its main features and founders, written in an informal style.

3276. Neményi, Paul F. "The Main Concepts and Ideas of Fluid Dynamics in Their Historical Development". *Archive for History of Exact Sciences* 2 (1962), 52–86.

The emphasis of this posthumous article lies on a description of the work of Leonardo da Vinci, Galileo, Torricelli, and Mariotte as leading to the work of Newton. There are several short sections dealing with the Bernoullis, Euler, d'Alembert, Bossut, and de Borda, while the "moderns" are briefly dismissed. Experiment is to the forefront, but this is one of the few references which tackle pre-Eulerian fluids. See also his "Wasserbauliche Strömungslehre" in *Handbuch der Physikalischen und Technischen Mechanik, Band 5, Mechanik der Flüssigkeiten nebst technischen Anwendungsgebieten* (Leipzig: Johann Ambrosius Barth, 1931), 967–1145.

3277. Rouse, Hunter, and Simon Ince. *History of Hydraulics.* Iowa City: State University of Iowa, 1957, xii + 269 pp. Reprinted with corrections from supplements to *La Houille Blanche,* 1954–1956. Reprinted with corrections New York: Dover, 1963.

This is a good introduction to the concepts of hydraulics, with the work of Euler and Johann Bernoulli somewhat neglected while that of d'Alembert is overblown. About one hundred references are located at the ends of the chapters. The history covers early antiquity to mid 20th century, with about two-thirds from the 17th century onwards. There is an even spread on engineering, mathematics, and personalities, but the level of reliability if not so even, and sources should be checked: "Little is known about [Ernst Heinrich and Wilhelm Eduard Weber]," say pp. 144–145, "except that they were Professors at Leipzig and Halle respectively." This "little known" Wilhelm Eduard Weber was at the center of one of the largest political storms of the 19th century in Germany, was the driving force in Gauss's work on the electric telegraph and electrodynamics and on terrestrial magnetism, and later did much electrodynamics on his own.

Review: Truesdell, Clifford, *Isis* 50 (1959), 69–71.

3278. Stokes, Sir George Gabriel. "Report on Recent Researches in Hydrodynamics". *Report of the Fifteenth Meeting of the British Association for the Advancement of Science, 1846, Part I.* London: John Murray, 1847, 1–46.

This is one of the earliest reviews of fluid dynamics, written by the man who began solving problems based on Laplace's equation rather than just laying down theory or solving one- and two-dimensional simple cases. It was extended by that of Hicks and complemented by that of Brillouin.

3279. Tani, Itiro. "History of Boundary-Layer Theory". *Annual Review of Fluid Mechanics* 9 (1977), 87–111.

This excellent historical review of boundary-layer theory has 30 references to the mathematics but is itself not heavily mathematical; it covers the period 1845–1970 in fluid mechanics, and the period 1905–1970 on boundary-layer theory in detail. It covers the spread of Prandtl's ideas, so vital in aerodynamics, but also gives credit to those who discovered these ideas independently and contemporaneously. Each volume in this series of reviews begins with a short personal or institutional history of about 10–20 pages.

3280. Tokaty, Grigori Alexandrovich. *A History and Philosophy of Fluid Mechanics.* Henley-on-Thames: Foulis, 1971, ix + 241 pp.

This complete history, from earliest times to the present, has about 400 references in its footnotes. It includes Russian contributions (19th to 20th century) not included in the reviews listed here, as well as German (19th to 20th century) and French (18th to 19th century). There is a good balance of mathematics, engineering, and history.

3281. Truesdell, Clifford A. "Notes on the History of the General Equations of Hydrodynamics". *American Mathematical Monthly* 60 (1953), 445–458.

This is an introductory, descriptive history covering Newton, Daniel Bernoulli, d'Alembert, Euler, Navier, Cauchy, Poisson, and Stokes, 1687–1845, and forms a preliminary to the great reviews, q.v.

3282. Truesdell, Clifford A. *The Kinematics of Vorticity.* (Indiana University Publications in Science Series, No. 19.) Bloomington: Indiana University Press, 1954, xviii + 232 pp.

This thorough study, historically based on the reviews in the *Leonhardi Euleri Opera omnia*, is fully documented with over 300 items in its bibliography. It is (relatively) easy to read, mathematically speaking, and concentrates on the geometry and kinematics of rotational motion and the vector fields and theorems attaching thereto.

Heat Conduction

Heat has been associated with problems in energy and its conservation and transformation, and with the development of the theory of crystals and their groups. The problem of heat conduction led to developments in differential geometry by Lamé and Riemann (see Reich's article under Elasticity), in series by Fourier, and in quantum theory by Planck, who also developed the theory of heat radiation.

The major histories of thermodynamics listed here are those by Mach, G. Bachelard, and Truesdell. The original source is Fourier, and the two works by Herivel and Grattan-Guinness show its practical and theoretical importance. For the principle of conservation of energy and its history one should consult the book by Elkana, particularly its appendix. Finally, the reviews by J. J. Burkhardt, Wiederkehr, and Wigner give good coverage of crystallography.

3283. Bachelard, Gaston. *Étude sur l'évolution d'un problème de physique: la propagation thermique dans les solides.* Paris: J. Vrin, 1927, 184 pp. Reprinted 1973, v + 183 pp.

This is a discussion of the history of the nature of heat, as a fluid or as movement; it discusses the work of Biot, Fourier and Comte, Duhamel, Lamé, and Boussinesq, in the 19th century. The mathematics tends to be treated rather than the models of heat conduction and of heat conduction through crystals; there are about 40 references.

3284. Burkhardt, J. J. "Zur Geschichte der Entdeckung der 230 Raumgruppen". *Archive for History of Exact Sciences* 4 (1967), 235–246.

This details priority investigations for Schoenflies, Barlow, Fedorov, and Sohnke, and has a bibliography of 80 titles.

3285. Elkana, Yehuda. *The Discovery of the Conservation of Energy.* Cambridge, Mass.: Harvard University Press, 1974, x + 213 pp.

This is a philosophical rather than a mathematical history. It deals with the work of Mayer, Joule, Thomson, Rankine, Helmholtz, and Carnot in an appendix on priority in the conservation of energy. There are nearly 300 references listed at the end. See also Erwin N. Hiebert, *Historical Roots of the Principle of Conservation of Energy.* (Madison: The State Historical Society of Wisconsin, 1962, 118 pp.).

3286. Grattan-Guinness, Ivor, in collaboration with J. R. Ravetz. *Joseph Fourier, 1768–1830: A Survey of His Life and Work, Based on a Critical Edition of His Monograph on the Propagation of Heat, Presented to the Institut de France in 1807.* Cambridge, Mass.: MIT Press, 1972, xii + 516 pp.

This reproduces the text of the 1807 essay with interspersed comments on the work. The survey fills about one-fifth of the book, and there are nearly 400 references in the footnotes and the bibliography. See also item 2312. This items needs to be supplemented by the next one.

3287. Herivel, John. *Joseph Fourier: The Man and the Physicist.* Oxford: Clarendon Press, 1975, xii + 350 pp.

This work is mainly biographical although two large chapters are devoted to mathematical-physical material. There is a substantial appendix giving English translations of 28 letters, and there are 100 references in the bibliography. The importance of these last three items lies in the fact that the thread linking Daniel Bernoulli, Fourier, Dirichlet, and Riemann has been transformed into a striking tapestry of partial differential equations and differential geometry, to say nothing of the work of Cantor in cardinality.

3288. Hiebert, E. N. *Historical Roots of the Principle of Conservation of Energy.* Madison, Wis.: State Historical Society of Wisconsin, 1962. Reprinted New York: Arno Press, 1981, 118 pp. (The Development of Science.)

3289. Lee, William H. K., ed. *Terrestrial Heat Flow.* (Geophysical Monograph Series, no. 8). Washington, D.C.: American Geophysical Union, 1965.

The first two articles, by Edward C. Bullard, "Historical Introduction to Terrestrial Heat Flow", pp. 1–6, and by John C. Jaeger, "Application of the Theory of Heat Conduction to Geothermal Measurements", pp. 7–23, contain 120 references to the history, theory, and applications for this topic in the period 1850–1960.

3290. Mach, Ernst. *Die Prinzipien der Wärmelehre. Historisch-kritisch entwickelt.* Leipzig: Johann Ambrosius Barth, 1896, viii + 472 pp. Reprinted in three further editions to 1923. There does not seem to be a complete translation into English.

This has the usual virtues of and suffers from the usual defects of Mach's work. Two references which may be used to guide one through the Mach-Planck controversy are: Ulrich Hoyer, "Von Boltzmann zu Planck", *Archive for History of Exact Science* 23 (1980), 47–86 (on entropy, with 40 references); and Hans Georg Schöpf, *Von Kirchhoff bis Planck: Theorie der Wärmestrahlung in historisch-kritischer Darstellung* (Braunschweig: Vieweg, 1978, 199 pp.).

3291. Scholz, Erhard. *Symmetrie—Gruppe—Dualität.* Basel, Boston, Berlin: Birkhäuser, 1989, 406 pp.

On the relation between theoretical mathematics and applications in crystallography and statics in the 19th century. Reviewed by Walter Purkert in **MR** 91j:01029.

3292. Shafranovskii, Ilarion Ilarionovich, *Istoriya Kristallografii: S drevneishikh vremen do nachala XIX stoletiya* (†The history of crystallography from earliest times to the beginning of the 19th century†), Leningrad: Nauka, 1978, 293 pp..

3293. Truesdell, Clifford A. *The Tragicomical History of Thermodynamics, 1822–1854*. New York: Springer, 1980, xii + 372 pp.

This is the full development of Truesdell's short course, delivered in three lectures at the International Centre for Mechanical Sciences in Udine, Italy, in 1971: *Tragicomedy of Classical Thermodynamics* (Courses and Lectures No. 70, Vienna and New York: Springer-Verlag, 1973, 41 pp.). The original "tragicomedy" had Fourier, Carnot, Clapeyron, Helmholtz, Clausius (on thermodynamics), and Gibbs (on thermostatics) in the leading roles of what was but a sketch. This history portrays the period 1800–1860, with emphasis placed on that in the title. The work of Fourier, Carnot, Clausius, the British School (Joule, Rankine, Thomson, and Helmholtz), and Reech is presented in detail. There are over 200 references listed as "sources" and there are several hundred others given in these sources and in the footnotes. The treatment is both historical and mathematical. See also item 3796.

3294. Wiederkehr, Karl Heinrich. "Das Weiterwirken der Haüyschen Idee von der Polyedergestalt der Moleküle in der Chemie, die Umgestaltung der Haüyschen Strukturtheorie durch Seeber und Delafosse, und Bravais' Entdeckung der Gittertypen". *Centaurus* 22 (1978), 177–186.

This is a good introduction to pre-group-theoretic crystal theory.

3295. Wigner, Eugene P. "Symmetry Principles in Old and New Physics". *Bulletin of the American Mathematical Society* 74 (1968), 793–815.

This review deals with symmetry and the invariance it induces, as seen in crystallography and in quantum mechanics. There are about 100 references at the end.

3296. Wise, M. Norton. "William Thomson's Mathematical Route to Energy Conservation: A Case Study of the Role of Mathematics in Concept Formation". *Historical Studies in the Physical Sciences* 10 (1979), 49–83.

The analogy of heat, fluid flow, magnetism, and mechanics based on the Laplace and Poisson equations is described and used to gently illustrate the development of concepts via mathematics. However, the physical side of Thomson's thinking is not played down. See also Crosbie W. Smith, "Natural Philosophy and Thermodynamics: William Thomson and 'the Dynamical Theory of Heat'". *British Journal of the History of Science* 9 (1976), 293–319, as this is the nonmathematical complement to the paper by Wise.

Sound and Vibrations

This theory begins with the papers by d'Alembert, and rapidly develops with work by Euler, Daniel Bernoulli, and Lagrange; the developments at the turn of the century due to Sophie Germain and Poisson, particularly in elasticity theory, lay the foundations for Rayleigh's treatise. On the practical side, there are corrections to Newton's results by Laplace, many developments in bells, bars, and instruments, and some of these are indicated.

The major text is Rayleigh's *Theory of Sound*. To these have been added the entertaining contributions by Bucciarelli and Dworsky, Lehr, and Miller, and the review by Lindsay. Further material can be found under Elasticity and Fluid Mechanics.

3297. Bucciarelli, Louis L., and Nancy Dworsky. *Sophie Germain: An Essay in the History of the Theory of Elasticity.* Dordrecht, Boston: D. Reidel, 1980, xi + 147 pp.

The title says elasticity but the subject is sound and vibrations based on elasticity; it stems from Chladni's patterns on vibrating circular discs, and from the attempts to form a theory to account for them come Lagrange's biharmonic equation and the molecular elasticity theory of Poisson (1814). The elasticity goes on to the efforts of Navier (1820) and Cauchy (1828). Additional references may be found in reviews by I. Grattan-Guinness, *Annals of Science* 38 (1981), 663–690, especially 670–671, and by J. J. Cross, *Annals of Science* 39 (1982), 85–88, where further references may be found. See also item 4776.

3298. Dostrovsky, Sigalia. "The Origins of Vibration Theory: The Scientific Revolution and the Nature of Music". Dissertation, Princeton University, 1969, v + 270 pp.

See also 4810.

3299. Dyment, S. A. "The Laplace Correction". *Science Progress* 26 (1931), 231–240.

This is a short history of the propagation of sound in air from 1660 to 1820, with 25 references.

3300. Hunt, Frederick Vinton. *Origins in Acoustics: The Science of Sound from Antiquity to the Age of Newton.* New Haven: Yale University Press, 1978, xv + 196 pp.

This history gives a thorough introduction to pre-Euler-Lagrange practice in acoustics, with about 400 references in the notes which are collected at the end of the book.

3301. Lehr, André. "On Vibration Patterns before Chladni". *Janus* 52 (1965), 113–120.

The tuning of bells in the Netherlands in the 17th century was done by means of bars of the correct tone. These bars were held fixed by bolts through holes drilled at nodes. The nodes were found by sprinkling sand on the bars, by then striking these bars, and by marking the places where the sand heaped together. The bells were sounded and fixed bars, sprinkled with sand, resonated, with good tuning making the sand grains leap and jump. This is a descriptive paper with accurate translations of the quotations from the sources.

3302. Lindsay, Robert Bruce. "The Story of Acoustics". *Journal of the Acoustical Society of America* 39 (1966), 629–644.

This is a general review of the history of sound from 1600 to 1960, with good references to the literature; it is not mathematical in itself.

3303. Miller, Dayton Clarence. *Anecdotal History of the Science of Sound to the Beginning of the 20th Century.* New York: Macmillan, 1935, xii + 114 pp.

This history is deceptively titled with the work "anecdotal," as it gives a good coverage of the topic, particularly of the 18th and 19th centuries. Further, it gives good comments on other histories and has 15 plates scattered throughout the text and 100 references at the end.

3304. Strutt, John William, Third Baron Rayleigh. *The Theory of Sound.* London: Macmillan, Volume I in 1877 and Volume II in 1878. Reprinted New York: Dover, 1945, with an historical introduction by Robert Bruce Lindsay, from one of the later editions.

This is a complete theory of sound, useful as an historical source because of the multitudinous references in the footnotes. It begins with a general theory of vibrations, and then deals with the vibration of strings, bars, membranes, and plates; the second volume deals with sound in air, air in chambers of various shapes and sizes.

Mechanics

This classical topic has three faces; potential theory and gravity (Poincaré), celestial mechanics (Poincaré, Wintner), and the mechanics of particles and rigid bodies (Kovalevskaya, Lagrange, Laplace, and I. Szabó). The General section above contains further references. Many classics due to Routh, Whittaker, Mathieu, and the well-known textbook writers of the last century have been omitted.

3305. Bos, H. J. M. "Mathematics and Rational Mechanics". In *The Ferment of Knowledge.* Edited by G. S. Rousseau and R. Porter. Cambridge: Cambridge University Press, 1980, 327–355.

Discusses changes in historiography of 18th-century mathematics and rational mechanics from Montucla's contemporary account through today in terms of changing pictures of that century. Recent developments are characterized as "taking concepts and context seriously."

3306. Fierz, Markus. *Vorlesgungen zur Entwicklungsgeschichte der Mechanik.* (Lecture Notes in Physics, No. 15.) Berlin: Springer, 1972, 97 pp.

This history covers the whole period from Plato to Newton, with emphasis on the 16th and 17th centuries: Copernicus, Kepler, Galileo, Huygens, and Newton. The two dozen references are not really sufficient; the treatment is not mathematical.

3307. Grigor′yan, Ashot Tigranovich. *Ocherki istorii mekhaniki v Rossii* (Notes on the history of mechanics in Russia). Moscow: Akademiia Nauk SSSR, 1961, 292 pp.

This history covers Russian contributions to mechanics, dynamics, stability, aerodynamics and general hydrodynamics, and elasticity. The coverage is mainly 19th and 20th centuries, and there are 600 references at the end. See also his *Ocherki istorii matematiki i mekhaniki: sbornik statei* (†Notes on the History of Mathematics and Mechanics: A Collection of Articles†) (Moscow: Akademiia Nauk SSSR, 1963, 272 pp.).

3308. Grigor′yan, Ashot Tigranovich. "On the Development of Variational Principles of Mechanics". *Archives Internationales d'histoire des Sciences* 18 (1965), 23–35.

This article concentrates on the Russian school using minimum principles in mechanics, particularly by Ostrogradski, Sludski, Joukovski, Talysin, Chaplygin, and Suslov, in the period 1850–1920. It is mathematical, with a dozen references.

3309. Körner, T. "Der Begriff des materiellen Punktes in der Mechanik des achtzehnten Jahrhunderts". *Bibliotheca Mathematica* 5 (1904), 15–62.

3310. Ravetz, Jerome R. "The Representation of Physical Quantities in 18th-Century Mathematical Physics". *Isis* 52 (1961), 7–20.

3311. Mach, Ernst. *Die Mechanik in ihrer Entwicklung. Historischkritisch dargestellt.* Leipzig: Brokchaus, 1883, x + 483 pp., and eight other editions to 1933. Translated into English in six editions as *The Science of Mechanics. A Critial and Historical Exposition of its Principles*, first done by Thomas J. McCormack. Chicago: Open Court, 1893, xiv + 534 pp., and five other editions to 1960.

This evergreen classic must be read carefully and checked against the original sources, especially for Galileo and the Bernoullis.

3312. Pogrebysskii, Iosif Benediktovich. *Ot Lagranzha k Einshteinu: Klassicheskaya mekhanika XIX veka* (†From Lagrange to Einstein:

Classical mechanics in the 19th century†). Moscow: Nauka, 1966, 326 pp.

This is a set of notes with 200 referencs at the very end. The notes cover the statics of Lagrange, Carnot, and Monge, as well as the dynamics of Lagrange; elasticity and hydrodynamics in the molecular style of Laplace, including the work of Poinsot as well; the analytical methods of Hamilton, C. G. J. Jacobi, and Ostrogradski; and the geometrization of mechanics under Darboux, Beltrami, and Lipschitz.

3313. Sharlin, Harold Issadore. "William Thomson's Dynamical Theory: An Insight into a Scientists's Thinking". *Annals of Science* 33 (1975), 133–147.

This article supplies some of the physical thinking so lacking in histories of mathematics. It gives very useful indications of Thomson's mode of argument in the vital period 1846–1851.

3314. Szabó, Istvan. *Geschichte der mechanischen Prinzipien und ihrer wichtigsten Anwendungen*. Basel, Stuttgart: Birkhäuser, 1977, xvi + 491 pp. 2nd ed. Basel, Boston: Birkhäuser, 1979, xviii + 491 pp., (Wissenschaft und Kultur, Bd. 32.)

This history attempts to cover the period 1600–1975. All of the hundreds of references appear in the footnotes, and the indexes are brief. There is a severe concentration on the classical and the linear, and the list of topics is necessarily highly selective: rigid-body mechanics of the 18th century; the mechanics of Eulerian fluids, viscous fluids and gas dynamics; linear, homogeneous, isotropic, elastic solid materials; impact. See the favorable review by Truesdell in *Centaurus* 23 (1980), 163–175.

3315. Truesdell, Clifford. "Whence the Law of Moment of Momentum?" *Mélanges Alexandre Koyré. Tome I, L'aventure de la science*. Edited by I. B. Cohen and R. Taton. Paris: Hermann, 1964, 588–612.

This is a brief "working-historian's" view of the separateness of this principle (from the principle of linear momentum), its basis and development, its use and meaning, and of the *Eulerian* equations of motion. There are about 30 references in the footnotes. This is reprinted with additions and illustrations in Truesdell's *Essays*, item 3245.

3316. Wintner, Aurel. *The Analytical Foundations of Celestial Mechanics*. Princeton: Princeton University Press, 1941, xii + 448 pp.

The three- and n-body problems are treated in some detail. This is the last of the analytical treatises before the topological flood; it summarizes the tradition of Hill, Poincaré, Levi-Civita, and G. D. Birkhoff. The historical part lies in the notes, pp. 411–443, where all the references are given for the sections of the text. See also Alfred Gautier's *Essai historique sur le problème des trois corps; ou, Dissertation sur la théorie* *des mouvements de la lune et des planètes, abstraction faite de leur figure* (Paris: Veuve Courcier, 1817, xii + 283 pp. + planche).

MATHEMATICS AND INSTRUMENTATION

Mathematical Instruments

The study of scientific instruments is one which has blossomed in the last thirty years. While there was no section on the relationship between the history of mathematics and the instruments employed in mathematical disciplines in the first edition of this bibliography, the importance of the expanding field of the history of scientific instruments has led to the inclusion of this new section. Before the seventeenth century, all instruments made came under the heading of "mathematical instruments" since they were all employed in the various different mathematical arts. Thus, works which are relevant to the history of mathematics are those concerning instruments of astronomy and navigation, of surveying and drawing, as well as those general works which cover all forms of scientific instruments. The literature is extensive and no attempt is made to provide a comprehensive list of reference works, but simply to provide an overview of the most important.

The creation of this list was greatly helped by the recent publication of an extremely useful general bibliography of scientific instruments:

3317. Turner, G. L' E., and D. J. Bryden. *A Classified Bibliography on the History of Scientific Instruments*. Oxford: Scientific Instruments Commission, 1997, iv + 119 pp.

This comprehensive bibliography covers all the books and articles on scientific instruments which were published between 1983 and 1995. The works are arranged into subject areas, with any which come under two or more categories appearing in all those which are relevant. Unfortunately the bibliography is not annotated, so recourse must be made to the actual works to be sure of their content. There are some items included from the period 1980-83, but no earlier works. Works relating to navigational instruments are included in the section "Mathematics and navigation".

Turner and Bryden's bibliography contains the majority of the important works in the history of scientific instruments. A selection of these is given below along with some of the older books which were not included in the recent bibliography but which were central to the early history of the discipline. With the exception of two volumes, no catalogues of collections of scientific instruments are included, since these are amply covered in Turner and Bryden.

Journals

3318. *Annals of Science*. London, 1936-.

This bi-monthly journal covers many aspects of the history of science, but is particularly strong on articles concerning scientific instruments.

3319. *British Journal for the History of Science.* Cambridge: Cambridge University Press, 1962-.

A quarterly journal concerned with the general history of science, but it occasionally carries papers on scientific instruments.

3320. *Bulletin of the Scientific Instrument Society.* London, 1983-.

This journal appears quarterly and provides the largest number of papers on scientific instruments to appear regularly in the U.K. The length of papers range from one-page notes to extensive studies.

Studies

3321. Anderson, R. G. W., J. A. Bennett, and W. F. Ryan, eds. *Making Instruments Count. Essays on Historical Scientific Instruments presented to Gerard L'Estrange Turner.* Aldershot: Variorum, 1993, xix + 492 pp.

3322. Behrends, Okko, and Luigi Capogrossi Colognesi. *Die römische Feldmesskunst.* Göttingen: Vandenhoeck & Ruprecht, 1992, 454 pp.

3323. Bennett, J. A. *The Divided Circle. A History of Instruments for Astronomy, Navigation and Surveying.* Oxford: Phaidon Christie's, 1987, 224 pp.

The best all-round introduction to the development of instruments in these three central disciplines of the applied mathematical sciences. Covers the Greek period to the 19th Century, with a brief glimpse of 20th-Century instruments.

3324. Bion, Nicolas. Translated by Edmund Stone. *The Construction and Principal Uses of Mathematical Instruments.* 2nd English edition, London, 1758; facsimile edition, London, 1972.

This one primary source is included, because it is the most detailed account available of the uses of a large number of the instruments relevant to this bibliography. Bion's explanations provide a clear method for using the instruments, as well as the means for their construction, and the volume is well-illustrated throughout. There is no modern work which has superseded the detail provided here.

3325. Blondel, Christine, Françoise Parot, Anthony Turner and, Mari Williams, eds. *Studies in the History of Scientific Instruments. Papers presented at the 7th Symposium of the Scientific Instruments Commission of the Union Internationale d'Histoire et de Philosophie des Sciences. Paris 15-19 September 1987.* London: Rogers Turner Books, 1989, 290 pp.

Twenty-five articles on various aspects of the history of scientific instruments.

3326. Bud, Robert and Deborah Jean Warner, eds. *Instruments of Science. An Historical Encyclopedia* New York and London: The Science Museum, London, and the National Museum of American History, Smithsonian Institution in association with Garland Publishing, 1998, xxv + 709pp.

An indispensable guide to over three hundred scientific instruments, including many mathematical instruments. Each entry is illustrated and has a short bibliography for further reference.

3327. Cajori, Florian. *A History of the Logarithmic Slide Rule and Allied Instruments*. London: Archibald Constable and Company, 1909, Reprinted in *String Figures and Other Monographs*. Edited by W. W. R. Ball et al. New York: Chelsea Publishing Company, 1960, 1969, vi + 136 pp.

Still the only comprehensive study of slide rules, and still regularly cited. See also item 2102.

3328. Chapman, Allan. *Dividing the Circle. The Development of Critical Angular Measurement in Astronomy 1500-1850*. 2nd edition, Chichester: John Wiley and Sons, in association with Praxis, 1995, 215 pp.

Detailed study of the development of accuracy in dividing circular scales for observational instruments. Also covers various aspects of the history of astronomy, with prominence given to the Royal Observatory at Greenwich. Very short bibliography.

3329. Clifton, Gloria. *Directory of British Scientific Instrument Makers 1550-1851*. London: Zwemmer, in association with the National Maritime Museum, 1995, xviii + 331 pp.

An invaluable repository of information on instrument makers throughout the British Isles.

3330. Cox, R. C., "The Development of Survey Instrumentation 1780-1980". *Survey Review* 28 (1986), 234-255 and 283-303.

3331. de Clercq, Steven, ed. *Nineteenth-Century Scientific Instruments and their Makers*. Leiden: Rodopi, 1985, vii + 275 pp.

This set of conference papers provides the most comprehensive single-volume coverage of instruments of the nineteenth century and their makers. The important transition from the eighteenth century is discussed for various countries in Europe and America. Indexed for names but not objects; no overall bibliography.

3332. Daumas, Maurice. *Scientific Instruments of the Seventeenth and Eighteenth Centuries and their Makers.* Translated and edited by Mary Holbrook. London: Portman Books, 1989, vi + 361 pp.

The original French edition of this work appeared in 1953, and it has largely been superseded by other works, but as yet there is no better general source on French instrument makers and their workshops.

3333. Field, J. V. "What is Scientific About a Scientific Instrument? *Nuncius* 3 (1988), 3-26. "

3334. Hackmann, Willem D. "Instrumentation in the Theory and Practice of Science: Scientific Instruments as Evidence and as an Aid to Discovery". *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* anno x (1985), 87-115.

3335. Hackmann, Willem D., and A. J. Turner, eds. *Learning, Language and Invention: Essays presented to Francis Maddison.* Aldershot and Paris: Variorum and The Société Internationale de l'Astrolabe, 1994, xv + 333 pp.

Both these festschrifts contain important essays on the history of scientific instruments. The former work (item 3321) is particularly relevant to the history of mathematical instruments.

3336. Warner, Deborah Jean. "What is a scientific instrument, when did it become one, and why?" *British Journal for the History of Science* 23 (1990), 83-93.

These three papers consider the nature of scientific instruments and their place in the history of science.

3337. Gouk, Penelope. *The Ivory Sundials of Nuremberg 1500-1700.* Cambridge: Whipple Museum of the History of Science, 1988, 144 pp.

3338. Lloyd, Steven A. *Ivory Diptych Sundials 1570-1750.* Cambridge, Massachussetts and London: Harvard University Press, 1992, 169 pp.

Two catalogues of ivory sundials (the second of the Harvard collection, the first of instruments in the Whipple Museum, Cambridge, and the Oxford Museum for the History of Science), both with important historical introductory essays.

3339. Hambly, Maya *Drawing Instruments 1580-1980.* London: Sotheby's Publications, 1988, 206 pp.

The only full-length study of this area of mathematical instruments. The first chapter includes some notes on the history before 1580.

Bibliography includes some early reference works as well as twentieth-century ones.

3340. van Helden, Albert, and Thomas L. Hankins, eds. *Instruments*. Published as *Osiris* 2nd series, 9 (1994), 250 pp.

A collection of essays covering various aspects of the history of scientific instrumentation.

3341. Howse, Derke. "The Greenwich List of Observatories". *Journal for the History of Astronomy* special number, 17 (1986).

This invaluable reference for the history of astronomical instruments gives data for instruments made between 1670 and 1850 in about 230 observatories worldwide. Information includes date of production, maker, relevant dimensions and some additional information on current location and bibliographical references.

3342. King, David A. *Islamic Astronomical Instruments*. London: Variorum Reprints, 1987, [366] pp.

Collection of essays by Professor King, one of the foremost scholars in the history of Arabic instrumentation.

3343. Lorch, Richard. *Arabic Mathematical Sciences*. Aldershot: Variorum, 1995, various pagings

Includes essays on Arabic astronomical instruments.

3344. Maddison, Francis. "Early Astronomical and Mathematical Instruments. A Brief Survey of Sources and Modern Studies". *History of Science* 2 (1963), 17-50.

Although this is now very dated in terms of modern texts it does provide a useful survey of major scientific collections, important libraries and the literature published before 1963.

3345. Morton, Alan Q., and Jane A. Wess. *Public and Private Science. The King George III Collection*. Oxford: Oxford University Press in association with the Science Museum, 1993, ix + 710 pp.

An impressively full catalogue of this important collection with detailed introductory essays. Much of the collection is devoted to instruments of natural philosophy but there are also numerous mathematical instruments and instruments of precision measurement. Very full bibliography.

3346. Richeson, A. W. *English Land Measuring to 1800: Instruments and Practices*. Cambridge, Massachussetts and London: The Society for the History of Technology and The M.I.T. Press, 1966, x + 214 pp.

Rather basic, but covers the important surveying instruments.

3347. Saunders, H. S. *All the Astrolabes.* Oxford: Oxford University Press, 1984, 101 pp.

A mathematical study of planispheric and universal astrolabes with explanations of their use. The historical material provided is brief but there is a useful set of definitions of terms associated with astrolabes.

3348. Taylor, E. G. R. *The Mathematical Practitioners of Tudor and Stuart England.* Cambridge: Cambridge University Press, 1954, xi + 442 pp.

3349. Taylor, E. G. R. *The Mathematical Practitioners of Hanoverian England.* Cambridge: Cambridge University Press, 1966, xv + 503 pp.

For instrument makers these (this item, plus item above 3348) have largely been superseded by Clifton (see item 3329), but both are still a useful source for both makers and mathematicians. Infuriating in the lack of references and bibliography, but worthwhile nonetheless. See also item 2303.

3350. Turner, A. J. *Mathematical Instruments in Antiquity and the Middle Ages. An Introduction.* London: Vade-Mecum Press, 1994, 161 pp.

3351. Turner, Anthony. *Early Scientific Instruments. Europe 1400–1800.* London: Sotheby's Publications, 1987, 320 pp.

These companion volumes (this item plus item 3350) provide a detailed study of instrumentation before the nineteenth century. Very full bibliographies in both.

3352. Turner, A. J. *Of Time and Measurement. Studies in the History of Horology and Fine Technology.* Aldershot: Variorum, 1993, xi + 300 pp.

Collected essays on many aspects of the history of time measurement. Those relating to sundials and precision instrumentation are relevant here.

3353. Turner, G. L' E.. *Nineteenth-Century Scientific Instruments.* London: Sotheby's Publications, 1983, 320 pp.

Best book devoted to 19th-Century instruments that is currently available. Arranged according to subject area. Useful bibliography.

3354. Turner, G. L' E.. "Scientific Instruments" In *Information Sources in the History of Science and Medicine.* Edited by P. Corsi, and P. Weindling. London and Boston: Butterworths Scientific, 1983, 243-259.

A good brief introduction to the field, with a very useful bibliography covering works published up till 1981.

3355. Turner, G. L' E. *Storia delle Scienze*. Vol. 1: *Gli strumenti*. General editor P. Galluzzi Turin: Einaudi, 1991 593 pp.

A fine work detailing the development of scientific instruments, followed by an extensive catalogue/dictionary of instruments, arranged according to subject area. Mostly by G. Turner but with contributions from other scholars. Unfortunately this work is only available in Italian.

3356. Tyacke, Sarah, ed. *English Map-Making 1500-1650*. London: British Library, 1983, 125 pp.

Essays on early English cartography and surveying which include two discussions of surveying instruments and their makers.

3357. Williams, Mari E. W. *The Precision Makers: A History of the instruments industry in Britain and France, 1870-1939*. London and New York: Routledge, 1994 viii + 216 pp.

A welcome work on this period of instrument making, which has been surprisingly little studied. No bibliography unfortunately.

3358. Williams, Michael R. *A History of Computing Technology*. Englewood Cliffs, New Jersey: Prentice-Hall, 1985, xi + 432 pp.

From early numbering systems to computers of the 1980s this book charts the development of calculational aids and modern computers. More than half the book is devoted to the 20th Century.

3359. Zinner, E. *Deutsche und Niederlandische Astronomische Instrumente Des 11 - 18 Jaahrhunderts*. München: Beck, 1956, x + 678 pp.

The best source for information on German instrument makers and their instruments.

Mathematics and Navigation

No early works on navigation are included though many of the primary sources provide the best explanations of the methods of navigation in earlier times. Instead those works are given which provide full bibliographies of primary sources from the sixteenth, seventeenth and eighteenth centuries, modern works included are those which cover the history of mathematical navigation. This section includes books on navigational instruments, but general books on mathematical instruments and their makers can be found in the section on mathematics and instrumentation.

Journal

3360. *Journal of the Institute of Navigation*. London, 1948-1971. Subsequently *Journal of Navigation*, 1972-.

This quarterly journal is mostly concerned with modern developments in navigation, but occasionally carries historical essays.

Studies

3361. Cotter, Charles H. *A History of Nautical Astronomy.* London: Hollis and Carter, 1968, xii + 387 pp.

This work is purely concerned with navigation from the time of the Babylonians and Phoenicians to the early 20th C. It provides a very detailed account, with useful appendices on spherical trigonometry and an extensive bibliography.

3362. Cotter, Charles H. *A History of the Navigator's Sextant.* Glasgow: Brown, Son and Ferguson, 1983, 226 pp.

Despite its title, this book begins with the origins of early angle-measuring instruments of navigation and works through to sextants for air navigation. The lack of an overall bibliography is rather annoying.

3363. Destombes, Marcel. *Contributions sélectionnées à l'Histoire de la Cartographie et des Instruments scientifiques.* Edited by Günter Schilder, Peter van der Krogt, and Steven de Clercq. Utrecht and Paris: HES Publishers and A. G. Nizet, 1987 xxiv + 568 pp.

Over 30 papers in French and English published between 1938 and 1985, many of which are relevant to the history of navigation.

3364. Fanning, A. E. *Steady As She Goes. A History of the Compass Department of the Admiralty.* London: HMSO, 1986, xlv + 462 pp.

Charts the development of the compass in England from 1837, with a very brief pre-history in the introduction.

3365. Hewson, J. B. *A History of the Practice of Navigation.* Glasgow: Brown, Son and Ferguson, 1951, 2nd edition 1983, viii + 295 pp.

Good coverage of the mathematical practices involved in navigation and the instruments used. First section divided into study of charts, compasses and instruments; second section devoted to ocean navigation. Full index but no bibliography.

3366. May, W. E., and Holder, L. *A History of Marine Navigation.* Henley-on-Thames: G. T. Foulis and Co Ltd, 1973, xv + 280 pp.

This is a somewhat frustrating study since it runs through the whole history of one aspect of navigation before proceeding to the next. This makes it difficult, for instance, to link the dates of developments in compasses and altitude-measuring instruments together. However, there is a useful bibliography of early sources on navigation.

3367. Mörzer Bruyns, W. F. J. *The Cross-Staff. History and Development of a Navigational Instrument.* Amsterdam: Vereeniging Nederlandisch Historisch Scheepvaart Museum, 1994, 127 pp.

A very detailed survey of the history of this instrument with a checklist of known surviving examples and a good bibliography.

3368. Needham, Joseph. *Science and Civilisation in China.* Vol. 4: *Physics and Physical Technology. Part III: Civil Engineering and Nautics.* Cambridge: Cambridge University Press, 1971, lvii + 931pp.

Needham turns his attention to the subject navigation with his customary diligence and exhaustive study.

3369. Randier, Jean. *Marine Navigational Instruments.* Translated from French by John E. Powell London: John Murray, 1980, 219 pp.

Basic introduction to the subject but well-illustrated.

3370. Stimson, Alan. *The Mariner's Astrolabe. A Survey of known surviving sea astrolabes.* Utrecht: HES Publishers, 1988, 191 pp.

Historical introduction, followed by a handlist.

3371. Taylor, E. G. R. *The Haven-finding Art. A History of Navigation from Odysseus to Captain Cook.* London: Hollis and Carter, 1956, 2nd edition, 1971, xii, 295 pp.

The second edition includes an appendix by Joseph Needham on navigation in medieval China.

3372. Waters, D. W. "English Navigational Books, Charts and Globes Printed Down to 1600". *Revista da Universidade de Coimbra* 33 (1985), 239-257.

A short but useful run through early English books on navigation. These are still some of the best sources for historical navigational techniques. No bibliography–all books have to be located in the main text.

3373. Waters, D. W. *The Art of Navigation in England in Elizabethan and Early Stuart Times.* London: Hollis and Carter, 1958, xxxix + 696 pp. 2nd edition, Greenwich: Trustees of the National Maritime Museum, 1978, 3 vols.

Still the best around for a detailed study of navigation in early modern England. There are particularly good sections on the use of arithmetic and logarithms in navigation. Detailed index to text for works published before 1640, and annotated bibliography for works published between 1640 and 1958. There is very little difference between the two editions. See also item 1960.

3374. Williams, J. E. D. *From Sails to Satellites. The Origins and Development of Navigational Science.* Oxford: Oxford University Press, 1992, ix + 310 pp.

The concern of this whole book is the history of the application of mathematics to navigation. It covers a time span from the earliest sea voyages to modern aeronautical navigation. A large part of the book is concerned with developments in the twentieth century, a subject which has received little coverage elsewhere.

NUMBERS AND NUMBER THEORY

This section of the bibliography canvasses a number of diverse but related topics, including the origins of counting, numbers and number systems, the history of arithmetic, combinatorics, elementary number theory and more advanced topics involving algebraic and analytic number theory, which begin to overlap with other sections of the bibliography, in particular with the sections on algebra and analysis. The history of numerical analysis is covered in a section of its own following this one. Cross-references to other sections of the bibliography have been used whenever possible to accommodate the interests of economy without sacrificing as wide a sampling as possible of the subjects considered here. Even so, except for the origins of counting and number systems as they evolved from ancient times to the present, this section of the bibliography concentrates primarily on aspects of number and number theory dating roughly from the Renaissance.

Numbers

3375. Ascher, Marcia, and Robert Ascher. *Code of the Quipu. A Study in Media, Mathematics and Culture.* Ann Arbor: University of Michigan Press, 1981. Reprinted as *Mathematics of the Incas: Code of the Quipu*, Mineola: Dover Publications, 1997.

A detailed, in-depth analysis of ancient Andean quipus, knotted cords, whose precise use has been much debated.

3376. Audisio, F. "Il numero π". *Periodico Matematico* 11 (1931), 11–42 and 149–150.

Brief account of the history of *pi*.

3377. Bortolotti, E. "Sul numero π". *Periodico Matematico* 11 (1931), 110–113.

A companion piece to item 3376.

3378. Bosteels, G. *La vie des nombres.* Namur: Ad. Wesmael-Charlier, 1960.

Discusses the history of the numerals from one to twenty, as well as basic arithmetic operations.

3379. Boyer, Carl B. "Fundamental steps in the development of numeration". *Isis* 35 (1944), 153–168.

A general survey, including five figures.

3380. Brainerd, C. J. *The Origins of the Number Concept.* New York: Praeger, 1979.

Concerns the cultural evolution of numbers, logical theories of number, and how numerical concepts are grasped in the course of human psychological development. This book tries to integrate all these subjects as part of a related whole. Chapters 6–11 are devoted to what the author terms "ontogenetic changes" in number concepts. Some of the material here appeared previously in serials like the *Journal of General Psychology*, etc.

3381. Cajori, Florian. "The Controversy of the Origin of Our Numerals". *Scientific Monthly* 9 (1919), 458–464.

Reviews theories of the time, especially those of Kaye and Carra de Vaux. Cajori favors a Hindu origin, but admits reliable evidence can be found no earlier than the 9th century. The earliest record of use of zero is an inscription in India dated to 867 A.D.

3382. Cajori, Florian. *A History of Mathematical Notations.* Chicago: Open Court, 1928–1929. 2 vols. Reprinted 1974.

Volume 1 is concerned with notations in elementary mathematics; Volume 2 is devoted to notations mainly in higher mathematics. The second volume ends with a discussion of empirical generalizations on the growth of mathematical notations. Both volumes are well illustrated. See also items 890, 1892.

3383. Dantzig, T. *Number, the Language of Science. A Critical Survey Written for the Cultured Non-Mathematician.* New York: The Free Press, 1967.

This is a standard popularization, first written in 1930, and issued in numerous editions since. Sarton, G. reviewed the book in *Isis* 16 (1931), 455–459, as well as subsequent editions in 20 (1934), 592, and 31 (1940), 475–476. There is also a French translation of the original edition published in Paris (Payot, 1931).

3384. Dhombres, J. *Étude epistemologique et historique des idées de nombre de mesure et de continu.* Nantes: U.E.R. de Mathématiques, 1976.

Duplicated manuscript. Discusses numeration, the number concept, real numbers, transfinite numbers, with an interesting chapter on "parallel" developments in Chinese mathematics.

3385. Gānguli, Sāradākānta. "The Indian Origin of the Modern Place-Value Arithmetical Notation". *American Mathematical Monthly* 39 (1932), 251–256.

See item 1514.

3386. Glathe, A. *Die chinesische Zahlen.* Tokyo: Deutsche Gesellschaft für natur- und völkerkunde Ostasiens, 1932.

On Chinese numbers; with 15 plates and 3 drawings.

3387. Green, D. R. "The Historical Development of Complex Numbers". *Mathematical Gazette* 60 (411) (1976), 99–107.

Brief survey, with references to Heron, Diophantos, Mahavira, Bhascara, Bar Chiia Abraham, Pacioli, Chuquet, Cardano, Bombelli, Descartes, Leibniz, Harriot, Cotes, de Moivre, Euler, Wallis, Argand, Wessel, Gauss, d'Alembert, Cauchy.

3388. Hartner, W. "Zahlen und Zahlensysteme bei Primitiv- und Hochkulturvölkern". *Paideuma* 2 (1943), 268–326.

A detailed, illustrated study of number-words and symbols in the languages and writing of many cultures, both primitive and highly developed.

3389. Hughes, B. B. "The Earliest Known Record of California Indian Numbers". *Historia Mathematica* 1 (1974), 79–82.

Discusses numeration in the 18th century among American Californian Indians.

3390. Kennedy, H. C. "Peano's Concept of Number". *Historia Mathematica* 1 (1974), 387–408.

Discusses the number concept, as well as Peano's postulates and the foundations of mathematics.

3391. Laugwitz, D. "Bemerkungen zu Bolzanos Grössenlehre". *Archive for History of Exact Sciences* 2 (1965), 398–409.

Argues that the analysis of Bolzano's work given by Rychlik, item 3399, and van Rootsellar, item 3398, are inadequate. Laugwitz argues that the major deficiency in Bolzano's work concerns a faulty definition, and furthermore, upon interpreting Bolzano's theory in terms of the infinitesimals he and Schmieden introduced in 1958 in "Eine Erweiterung der Infinitesimalrechnung", *Mathematische Zeitschrift* 69 (1958), 1–39, Bolzano's theory can be made entirely consistent and rigorous.

3392. Maor, Eli. *e: The Story of a Number.* Princeton, N.J.: University Press, 1994. xiv + 223 pp.

3393. Mazaheri, A. "Formes 'sounites' et formes 'Chi'ites' des chiffres arabes au les avatars de chiffres indiens en Islam". *Proceedings of the XIIth International Congress for the History of Science (1971).* Moscow: Editions "Nauka," 1974, Section IV, 60–63.

Considers Sunnite and Shiite forms of Arabic numerals and the avatars of Indian numerals in Islam, concentrating on the 11th to the 15th centuries.

3394. Menninger, K. *Zahlwort und Ziffer. Eine Kulturgeschichte der Zahl.* Göttingen: Verlag Vandenhoeck & Ruprecht, Vol. 1: Zahlreihe und Zahlsprache, 1957; Vol. 2: Zahlschrift und Rechnen, 1958. Third edition, 1979. 2 vols.

First published in 1934, Menninger's classic work on the subject of number and numerals was translated into English in 1969 (see item 3395).

Volume 1 concerns number sequences and the words or language of counting. Volume 2 is devoted to the writing of numbers and to the development of computation and various arithmetic operations. With 170 illustrations.

Review: Fehr, H. F., *American Mathematical Monthly* 66 (1959), 437.

Hofmann, J. E., *Archives internationales d'Histoire des Sciences* 10 (1957), 255; 11 (1958), 199–200.

3395. Menninger, K. *Number Words and Number Symbols; a Cultural History of Numbers*. Translated by P. Broneer. Cambridge, Mass.: MIT Press, 1969. Reprinted, New York: Dover Publications, 1992.

A translation of item 3394 but omits the bibliography.

3396. Miller, G. A. "Historical Note on Negative Numbers". *American Mathematical Monthly* 40 (1933), 4–5.

3397. Mitchell, U. G., and M. Strain. "The Number *e*". *Osiris* 1 (1936), 176–196.

3398. Rootselaar, B. van. "Bolzano's Theory of Real Numbers". *Archive for History of Exact Sciences* 2 (1964), 168–180.

Rootselaar offers a different view of Bolzano's theory of real numbers and its deficiencies than those presented by Rychlik, item 3399. Above all, he opposes the view that Bolzano's theory can be refined to make it rigorous by showing that it is inherently inconsistent. Virtually no bibliography. See also Laugwitz, item 3391.

3399. Rychlik, K. *Theorie der reellen Zahlen in Bolzanos handscriftlichem Nachlasse*. Prague: Rieger, 1962.

Presents Bolzano's theory of real numbers based primarily upon manuscripts and other original sources. See also items 3391 and 3398.

3400. Sarton, George. "Decimal Systems Early and Late". *Osiris* 9 (1950), 581–601.

Includes two figures.

3401. Scriba, C. J. *The Concept of Number*. Manheim: Hochschultaschenbücher. Bibliographisches Institut, 1968.

A fundamental study that provides a basic introduction to the development of the number concept.

3402. Sergescu, P. "Histoire du nombre". *Conférences du Palais de la Découverte, 23*. Paris: Université de Paris, 1953. Review: Kraitchik, M., *Archives internationales d'Histoire des Sciences* 9 (1955), 78.

3403. Smeltzer, D. *Man and Number. An Account of the Development of Man's Use of Number Through the Ages.* New York: Emerson Books, 1958. Second edition, 1970.

A short, general introduction with bibliography.

3404. Smith, David Eugene. "The Roman Numerals". *Scientia* 40 (1926), 1–8 and 69–78.

Part 1 considers the origins of Roman numerals; Part 2 discusses other problems associated with their history.

3405. Solomon, B. S. "'One is no number' in China and the West". *Harvard Journal of Asiatic Studies* 17 (1954), 253–260.

3406. Thureau-Dangin, François. "Sketch of a History of the Sexagesimal System". Translated by S. Gandz. *Osiris* 7 (1939), 95–141.

Revised version of the author's *Esquisse d'une histoire du système sexagesimal* (Paris: Geuthner, 1932).

3407. Van der Waerden, Bartel Leendert. "Hamilton's Discovery of Quaternions". *Mathematics Magazine* 49 (1976), 227–234.

Discusses the origins of quaternions, as well as division algebras, octonians, and complex numbers in general, with references to Hamilton's notes and letters.

3408. Wieleitner, H. "Zur Frühgeschichte des Imaginären". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 36 (1927), 74–88.

Survey of contributions, especially those of Cardano and Bombelli, with special reference to the work of Bortolotti on the subject.

Number Systems

3409. Glaser, A. *History of Binary and Other Nondecimal Numeration.* Southampton, Pa.: A. Glaser, 1971; Los Angeles: Tomash Publishers, 1981.

Based on the author's dissertation at Temple University, with the title "History of Modern Numeration Systems." It opens with consideration of the work of Harriot, and continues to the present. Discusses the question of which base is best, and offers bibliographies of primary and secondary sources, chapter by chapter. The appendix to the 1981 edition includes a photo-reproduced copy of Fontennelle's article, "Nouvelle arithmétique binaire", 1703.

3410. Guitel, T. *Histoire comparée des numeration ecrite.* Paris: Flammarion, 1975.

Covers such topics as numeration in general, Egyptian, Aztec, Greek, Roman, Arabic, Hebrew, Ethiopian, Sumerian, Babylonian, Mayan, Chinese, and Indian numeration, including discussion of zero. Numerous illustrations and tables, with classification of 25 numeration systems, are also included.

3411. Laki, K. “The Number System Based on Six in the Proto Finno-Ugric Language”. *Journal of the Washington Academy of Sciences* 50 (1960), 1–11.

3412. Petrosyan, G. B. “Ob alfavitnykh sistemakh schisleniya”. *Istoriko-Matematicheskie Issledovaniia* (1978), 144–155.

Discusses alphabetic numeration systems and how to carry out arithmetic operations in such systems.

3413. Powell, Marvin A. “The Antecedents of Old Babylonian Place Notation and the Early History of Babylonian Mathematics”. *Historia Mathematica* 3 (1976), 417–439.

Argues for an earlier origin than has been claimed previously.

3414. Shirley, John W. “Binary Numeration before Leibniz”. *American Journal of Physics* 19 (1952), 452–454.

3415. Shrader-Frechette, M. “Complementary Rational Numbers”. *Mathematics Magazine* 51 (1978), 90–98.

Discusses the history of studies concerning patterns of digits found in repeating decimals.

Counting and the Abacus

3416. Barnard, F. P. *The Casting-Counter and the Counting Board. A Chapter in the History of Numismatics and Early Arithmetic*. Oxford: Clarendon Press, 1916.

Somewhat out of date on the subject of arithmetic, but still useful on the subject of counting boards.

3417. Closs, M. P. “The Nature of the Maya Chronological Count”. *American Antiquity* 42 (1977), 18–27.

Covers Mayan mathematics, numeration, and aspects of time.

3418. Evans, Gillian R. “*Duc oculum.* Aids to Understanding in Some Medieval Treatises on the Abacus”. *Centaurus* 19 (1976), 252–263.

Surveys 11th- and 12th-century treatises on arithmetic, especially those used in education. Also covers numeration in general and fractions. See also item 1801.

3419. Evans, Gillian R. “From Abacus to Algorism: Theory and Practice in Medieval Arithmetic”. *British Journal for the History of Science* 10 (1977), 114–131.

See item 1805.

3420. Kimble, G. W. "From Pebbles to Position". *Historia Mathematica* 6 (1979), 323–325.

Note on positional counting systems.

3421. Maistrov, L. E. "Rol alfabitnykh sistem numeratsii". *Istoriko-Matematicheskie Issledovaniia* 19 (1974), 39–49.

Discusses various opinions concerning the origin and role of alphabetical systems in numeration, particularly in Greek mathematics.

3422. Marschak, A. *The Roots of Civilization. The Cognitive Beginnings of Man's First Art, Symbol and Notation.* New York: McGraw-Hill, 1972. Revised and expanded edition, Mount Kisco, N.Y.: Moyer Bell, 1991.

Investigates prehistoric artifacts in connection largely with numeration and calendars. Many illustrations, with a good index, bibliography, and sources.

3423. Moon, P. *The Abacus.* New York: Gordon and Breach, 1971.

Although history comprises only a small portion of this book, descriptions of counting boards, as well as Chinese, Japanese, Roman, and Russian abacuses make this a useful source.

3424. Seidenberg, A. "The Ritual Origin of Counting". *Archive for History of Exact Sciences* 2 (1962), 1–40.

This article begins with a discussion of number-mysticism and ritual, considers the evidence of counting rituals, tabus on counting, stones, taxation, money, ordinal names, etc. The basic hypothesis is that counting was invented as a means of calling participants in a ritual onto the ritual scene. Extensive bibliography. See also items 1529 and 4213.

Arithmetic

3425. Auluck, F. C., ed. "Proceedings of the Symposium on al-Bīrūnī and Indian Sciences held at New Delhi on November 8–9, 1971". *Indian Journal of the History of Science* 19 (2) (1975), 89–276.

Twenty-five papers, including Brahmagupta and Bag on Bīrūnī and Indian arithmetic.

3426. Detlefsen, M., D. Erlandson, H. J. Clark, and C. Young. "Computation with Roman Numerals". *Archive for History of Exact Sciences* 15 (2) (1976), 141–148.

Simple procedures for adding and multiplying Roman numerals are given to show that computation with Roman numerals is not so difficult—or impossible—as is often held.

3427. Eganyan, A. M. *Grecheskaya logistika*. Yerevan: Erevanskii Armyanskii Gosudarstvennyi pedagogicheskii institut imeni Kh. Abovyana, 1972.

A critical review of secondary literature on Greek arithmetic from Nesselmann (1842) through Vogel's classic study (1936), and more recent work as well. Analysis of ancient and medieval sources is also included.

3428. Fettweis, E. "Streitfragen aus der Geschichte der Arithmetik in ethnologische Beleuchtung". *Scientia* 88 (1953), 235–249.

3429. Gillings, R. J. "Tests of Divisibility". *Scripta Mathematica* 22 (1956), 294–296.

3430. Hermelink, H. "The Earliest Reckoning Books Existing in the Persian Language". *Historia Mathematica* 2 (1975), 299–303.

Discusses 11th-century Persian arithmetic, especially that of Abū Ja'far Muh. b. Ayyūb Tabarī.

3431. Itard, J. *Arithmétique et théorie des nombres*. Paris: Presses Universitaires de France, 1963. Review: Taton, R. *Revue d'Histoire des Sciences* 17 (1964), 168–169.

3432. Karpinski, Louis C. *The History of Arithmetic*. New York: Russell & Russell, 1965.

First published, New York: Rand McNally, 1925. Review: Cajori, F., *Isis* 8 (1926), 231–232.

3433. Lam, Lay Yong. "The *Jih yung suan fa*: An Elementary Arithmetic Textbook of the Thirteenth Century". *Isis* 63 (1972), 370–383.

3434. Nordgaard, M. A. "The Origin and Development of Our Present Method of Extracting the Square and Cube Roots of Numbers". *Mathematics Teacher* 17 (1924), 223–238.

3435. Saidan, A. S., ed. *Arabic Arithmetic. The Arithmetic of Abū al-Wafā' al-Būzajānī, 10th Century, Mss. Or. 103 Leiden and 40 M Cairo*. Amman, Jordan: Jordanian University, 1971.

Entirely in Arabic, with introduction, commentaries, and ample references to the arithmetic of al-Karaji. Discusses Arab mathematics, arithmetic, Babylonian mathematics, Greek mathematics, sexagesimal systems, finger reckoning. Review: King, D., *Isis* 64 (1976), 123–125.

3436. Smith, C. S. "A Seventeenth-Century Octonary Arithmetic". *Isis* 66 (1975), 390–394.

Reproduces in facsimile two pages of notes in a contemporary volume.

3437. Taton, René. *Histoire de calcul.* (Collection Que Sais-Je?, No. 198.) Paris: Presses Universitaires, 1946. Review: "Sergescu, P.", *Archives internationales d'Histoire des Sciences* 1 (1947), 182.

3438. Taton, René. "L'évolution d'une operation: la multiplication". *La Nature* 76 (1948), 268–271.

Combinatorics

3439. Biggs, Norman L. "The Roots of Combinatorics". *Historia Mathematica* 6 (1979), 109–136.

History to 1650.

3440. Biggs, Norman L.; E. Keith Lloyd; Robin J. Wilson. "The History of Combinatorics", in *Handbook of Combinatorics*, Vol. 1, 2, 2163–2198, Elsevier, Amsterdam, 1995.

This is a useful overview of the history of combinatorics divided into eight sections: combinatorics in antiquity; origins of modern combinatorics; formal methods of enumeration, partitions and symmetric functions; the development of graph theory, configurations and designs; combinatorial set theory; and algorithmic combinatorics. As the authors admit, some prominent areas are not covered such as the Arabic contributions, and M. Mersenne and James Bernoulli. The bibliography consists of some 200 items. Eberhard Knobloch notes in **MR** 96j:05002 that research literature written in German and French is nearly completely overlooked, a substantial drawback for any history.

3441. Knobloch, E. "Die mathematischen Studien von G. W. Leibniz zur Kombinatorik, auf Grund fast ausschliesslich handscriftlicher Aufzeichnungen dargelegt und Kommentiert". *Studia Leibnitiana Supplementa* 11 (1973).

This study of Leibniz's contributions to combinatorics was followed several years later by a volume of texts, *Studia Leibnitiana Supplementa* 16 (1976), 339 pp. See also items 2171 and 2172.

3442. Knobloch, E. "Marin Mersennes Beiträge zur Kombinatorik". *Sudhoffs Archive* 58 (1974), 356–379.

Contents and probable origins of Mersenne's contributions to combinatorics.

3443. Knobloch, E. "Die mathematischen Studien von G. W. Leibniz zur Kombinatorik". *Janus* 63 (1976), 1–26.

Discusses Leibniz, his manuscripts, and his followers, including Weingartner, Stern, Hindenburg, and Boscovitch.

Logarithms

3444. Adams, C. W. "When Was Logarithmic Paper First Used? Answer to Query No. 80". *Isis* 30 (1939), 95–96. *Isis* 31 (1940), 429–430.

Answers were also given by G. Sarton, *Isis* 30 (1939), 95–96, and W. F. Durand, *Isis* 32 (1947), 117. Durand actually had a hand in the development of logarithmic paper.

3445. Ayoub, Raymond. "What is a Napierian Logarithm?" *Amer. Math. Monthly* 100 (1993), no. 4, 351–364.

An account of the contents and impact of John Napier's (1550–1617) *Mirifici logarithmorum canonis descripto* (†Description of the Wonderful Canon of Logarithms†) (1614) and *Mirifici logarithmorum canonis constructio* (†Construction of the Wonderful Canon of Logarithms†) (1619).

3446. Bruins, E. "Computation of Logarithms by Huygens". *Janus* 65 (1978), 97–104.

Historical discussion of Huygens's method of 1661, including references to Bürgi, Napier, Briggs, and Decker.

3447. Campbell-Kelly, Martin. "Charles Babbage's Table of Logarithms (1827)." *Ann. Hist. Comput.* 10 (1988), no. 3, 159–169.

Charles Babbage in 1827 published his table of logarithms of the natural numbers, from 1 to 108,000. Generally considered to be the most accurate of his day they were reprinted on numerous occasions, well into the 20th century. This paper describes Babbage's motivation for producing the tables, and the measures taken to ensure their accuracy. An assessment is given of Babbage's contribution to the art of table making.

3448. Eccarius, W. "Alexander von Humboldts Bemühungen um Additionslogarithmen". *NTM-Schriftenreihe für Geschichte der Naturwissenschaften, Technik, und Medizin* 16 (1979), 30–42.

Transcription with notes of two early manuscripts on logarithms by von Humboldt.

Number Theory

3449. Archibald, Raymond Clare. "Perfect Numbers". *American Mathematical Monthly* 28 (1921), 140–153.

3450. Archibald, Raymond Clare. "Quadratic Diophantine Equations". *Scripta Mathematica* 2 (1933), 27–33.

3451. Archibald, Raymond Clare. "Goldbach's Theorem". *Scripta Mathematica* 3 (1935), 44–50.

3452. Baker, A. "Some Historical Remarks on Number Theory". *Historia Mathematica* 2 (1975), 549–553.

Discusses primarily the Catalan Conjecture.

3453. Barnes, C. W. "The Representation of Primes of the Form $4n + 1$ as the Sum of Two Squares". *L'Enseignement Mathématique* 18 (1972), 289–299.

Discusses primarily the work of Legendre on representing a prime as the sum of two squares. Continued fraction constructions are also discussed.

3454. Bateman, P., and H. Diamond. "John E. Littlewood (1885–1977). An Informal Obituary". *Mathematical Intelligencer* 1 (1978), 28–33.

Discusses Littlewood's contribution to analytic number theory, as well as to analysis. Collaborations with Hardy and others are also discussed.

3455. Berndt, B. C. "Ramanujan's Notebooks". *Mathematics Magazine* 51 (1978), 147–164.

Offers detailed descriptions of the more interesting entries in Ramanujan's notebooks, along with a history touching on number theory, special functions, and series, as well as general biographical information and general content of the notebooks. The notebooks have been published in five parts to date: Bruce Berndt, *Ramanujan's notebooks*, New York: Springer-Verlag, 1991–1998.

3456. Cassels, J. W. S., and R. C. Vaughan. "Ivan Matveevich Vinogradov, 14 September 1891–20 March 1983". *Biographical Memoirs of Fellows of the Royal Society* 31 (1985), 613–631.

The subject of this review was distinguished for his use of finite trigonometric series to solve difficult problems of number theory.

3457. Collison, M. J. "The Origins of the Cubic and Biquadratic Reciprocity Laws". *Archive for History of Exact Sciences* 17 (1977), 63–69.

The author shows that Gauss developed new proofs of the quadratic reciprocity law in order to find methods applicable to the theory of cubic and biquadratic residues. The dispute between Eisenstein and C. G. J. Jacobi over priority of proofs of the cubic and biquadratic reciprocity laws is described.

3458. Dickson, L. E. *History of the Theory of Numbers.* Washington, D.C.: The Carnegie Institution, 1919–1923. Reprinted New York: Stechert, 1934, New York: Chelsea, 1952, 1971, xii + 486, xxii + 803, iv + 313 pp. 3 vols.

Ore described this work as "a complete, encyclopedic account of the history of the discoveries in number theory up to 1918." Volume 1 is devoted to divisibility and primality; volume 2 covers Diophantine analysis; volume 3 takes up quadratic and higher forms, with a chapter on the class number by G. H. Cresse. The work was reviewed as each volume appeared. Reviews: Child, J. M., *Isis* 3 (1920), 446–448; *Isis* 4 (1921), 107–109; *Isis* 6 (1924), 96–98.

3459. Dickson, L. E. "Perfect and Amicable Numbers". *Scientific Monthly* 12 (1921), 349–354.

3460. Drake, R. C. *A Developmental Study of Ideal Theory*. Dissertation, American University, *Dissertation Abstracts* 37 (1976), 797-B.

Treats development of Ideal Theory from its origins in Fermat's Last Theorem and algebraic number theory, as well as in certain polynomial rings and algebraic geometry. Emphasis is given to Kummer, Dedekind, and Kronecker.

3461. Dress, F. "Théorie additive des nombres, problème de Waring et théorème de Hilbert". *L'Enseignement Mathématique* 18 (1972), 175–190.

Treats additive number theory, Waring's problem, Hilbert's Theorem, sums of powers of integers, etc. Errata on pp. 301–302.

3462. Edwards, H. M. *Riemann's Zeta Function*. New York: Academic Press, 1974.

History of the prime number theorem, the Riemann hypothesis, and study of the Riemann zeta function, including analysis of the works of Chebyshev, Hadamard, Hardy, Mangoldt, Stieltjes, Littlewood, and others. A translation of Riemann's famous paper of 1859, "On the Number of Primes Less Than a Given Magnitude", is also included.

3463. Ellison, W., and F. Ellison. "Théorie des nombres". In *Abrégé d'histoire des mathématiques*. Vol. I. Edited by J. Dieudonné. Paris: Hermann, 1978, 165–334.

The Ellisons trace the route from Gauss to Hilbert and modern class-field theory, and also look at work on Diophantine equations and sieves.

3464. Frewer, Magdalene. *Das wissenschaftliche Werk Felix Bernstein*. Göttingen: Institut für Mathematische Statistik, 1977.

A full-length study of Bernstein's contributions to set theory, number theory, geometry, statistics, and genetics.

3465. Gendrikhson, N. N. "O nekotorykh rabotakh Gaussa po teorii algebraicheskikh chisel". *Problemy istorii matematiki i mekhaniki* 1 (1972), 56–60.

Discusses Gauss's work on the theory of algebraic numbers, including cyclotonic fields. The extent to which Gauss's unpublished work anticipated later developments, including Kummer's work and the concept of ideal factors, is explored.

3466. Goldstein, Catherine. *Un théorème de Fermat et ses lecteurs*. Saint-Denis: Presses Universitaires de Vincennes, 1995, 229 pp.

On Fermat's theorem that there is no right triangle with integral sides whose area is a square. Proofs based on the method of infinite descent were given by Fermat himself (using natural numbers) and by Frénicle de Bessy (constructing a sequence of triangles, around 1650). This inspiring study investigates by means of this example the perception, evolution, and transformation of a piece of mathematics, as seen by mathematicians on the one hand, and by historians of mathematics (down to the present) on the other.

3467. Goodstein, L. J. "A History of the Prime Number Theorem". *American Mathematical Monthly* 80 (1973), 599–615.

Concentrates on developments from Euler to Hadamard and Vallée-Poussin, with selected bibliography, samples, and corrections of Gauss's tables, as well as a translation of a letter from Gauss to Encke of December 24, 1849. See also item 3468.

3468. Goodstein, L. J. "Correction to 'A History of the Prime Number Theorem'". *American Mathematical Monthly* 80 (1973), 1115.

Corrects an earlier assertion in item 3467 that the sieve of Eratosthenes had appeared in Euclid's *Elements*.

3469. Halasz, G. "The Number-Theoretic Work of Paul Turan". *Acta Arithmetica* 37 (1980), 9–19.

Includes number theory, power sum method, zeta function, partitions, and uniform distributions.

3470. Hardy, G. H. *Ramanujan: Twelve Lectures on Subjects Suggested by His Life and Work*. Cambridge, England: Cambridge University Press, 1940.

This book opens with a biographical essay, "The Indian Mathematician Ramanujan," pp. 1–21. The eleven lectures which follow are meant to demonstrate the actual and original achievements of Ramanujan, especially on the theory of prime numbers, the analytic theory of numbers, partitions, representation of numbers as sums of squares, and Ramanujan's function.

3471. Hofmann, Joseph E. "Über zahlentheoretische Methoden Fermats und Eulers, ihre Zusammenhänge und ihre Bedeutung". *Archive for History of Exact Sciences* 1 (1961), 122–159.

This article offers a detailed discussion of the number-theoretic results of Fermat and Euler, compares their methods, investigates specific problems like Pythagorean triples, the four-cube problem $x^3 + y^3 = a^3 + b^3$, rational points on curves, etc. Extensive footnotes and bibliographic sources are provided, as well as a complete name index. See also item 2097.

3472. Holzer, L. "Eulers Forschungen in seiner Anleitung zur Algebra vom Standpunkt der modernen Zahlentheorie". *Sammelband zu Ehren des 250. Geburtstages Leonhard Eulers*. Berlin: Akademie-Verlag, 1959, 209–223. Review: Ore, O., *Mathematical Reviews* 23 (1962), 4, **MR** 23 #A36.

3473. Lee, E. J., and J. S. Madachy. "The History and Discovery of Amicable Numbers". *Journal of Recreational Mathematics* 5 (1972), 77–93.

This article is written in several parts, and discusses the work of Ore and amicable numbers. Part 1 discusses chronology of discovery and rediscovery of pairs of amicable numbers, while parts 2 and 3 offer tables of the 1,107 known amicable pairs (as of 1972), with a classification and a table listed by discoverer and type.

3474. LeLionnais, F., ed. *Great Currents of Mathematical Thought.* Translated by R. A. Hall and H. G. Bergmann. New York: Dover, 1971. 2 vols.

Volume I includes essays by various distinguished French mathematicians on diverse subjects, including the number concept, Fermat's Last Theorem, Kummer's ideal numbers, transfinite numbers, cardinal numbers, ordinal numbers, pi, etc. Volume II deals with mathematics in the arts and sciences.

3475. Matvievskaya, G. P. "Teoriya kvadratichnykh irratsialnostei i teoriya otnoshenii v evrope do XVII v" (†The theory of quadratic irrationals and the theory of ratio in Europe to the XVIIth century†). *Proceedings of the XIIIth International Congress for the History of Science, 1971, 4*. Moscow: Nauka, 1974, 77–80.

Theories of irrational numbers, ratio, and proportion, concentrating largely on medieval mathematics.

3476. Melnikov, I. G. "Voprosy teorii chisel v tvorchestve Ferma i Eilera". *Istoriko-Matematicheskie Issledovaniia* 19 (1974), 9–38.

Discusses number theory in the works of Fermat and Euler.

3477. Mirsky, L. "In Memory of Edmund Landau, Glimpses from the Panorama of Number Theory and Analysis". *The Mathematical Scientist* 2 (1977), 1–26.

Sketch of Landau's life and outline of his achievements as discoverer and teacher in both number theory and analysis, with some indication of his influence on others.

3478. Neumann, O. "Bemerkungen aus heutigen Sicht über Gauss' Beiträge zu Zahlentheorie, Algebra und Funktionentheorie". *NTM-Schriftenreihe für Geschichte der Naturwissenschaften, Technik und Medizin* 16 (1979), 22–39; 17 (1980), Heft 1, 32–48, Heft 2, 38–58.

Comments on contemporary assessments of Gauss's contributions to number theory, algebra, and the theory of functions.

3479. Ore, Øystein. *Number Theory and Its History.* New York, Toronto, London: McGraw-Hill, 1948, x + 370 pp. Reprinted New York: Dover, 1988.

Based on a lecture course on the theory of numbers and its history given over several years at Yale University. Presents "the principal ideas and methods of number theory as well as their historical background and development through the centuries." Includes chapters on counting and the recording of numbers, numerology and various number systems, Euclid, prime numbers, perfect and amicable numbers, Diophantine problems, congruences, theorems in number theory due to Fermat and Euler, as well as a chapter on the converse of Fermat's theorem and the classical construction problems, with emphasis on regular polygons, as well as the theory of decimal expansions.

3480. Paiow, M. "Die mathematische Staatsstelle. II". *Archive for History of Exact Sciences* 12 (1974), 174–185.

Considers the passage in Plato's *Republic* on the subjects of nuptual and geometric numbers.

3481. Pieper, H. *Variationen über ein zahlentheoretisches Thema von Carl Friedrich Gauss.* Basel: Birkhäuser, 1978.

Discusses Gauss's quadratic reciprocity theorem, with 14 variations on his results, including those by Lejeune-Dirichlet, Legendre, König, Eisenstein, Frobenius, Hensel, Mirimanoff, and Kronecker.

3482. Pieper, Herbert. "Über Legendres Versuche, das quadratische Reziprozitätsgesetz zu beweisen". Natur, Mathematik und Geschichte. *Acta Hist. Leopold.* No. 27 (1997), 223–237.

On Legendre's attempts to prove the quadratic reciprocity law.

3483. Roquette, Peter. "Zur Geschichte der Zahlentheorie in den dreißiger Jahren. Die Entstehung der Riemannschen Vermutung für Kurven, und ihres Beweises im elliptischen Fall. *Math. Semesterber.* 45 (1998), no. 1, 1–38. "

On the history of number theory in the 1930s. The evolution of the Riemann hypothesis for curves, and its proof in the elliptic case.

3484. Ross, B. "Euler's Letter to Goldbach Announcing the Discovery of an Integral Representation for X!" *Ganita Bharati: Bulletin of the Indian Society for History of Mathematics* 1 (1979), 9–12.

Translates Euler's letter of January 8, 1730, into English.

3485. Saidan, A. S. "Number Theory and Series Summations in Two Arabic Texts". *Proceedings of the First International Symposium for the History of Arabic Science. Vol. II.* (Papers in European Languages.) Edited by A. Y. al-Hassan, et al. Aleppo, Syria: Institute for the History of Arabic Science, 1978, 145–163.

Concentrates on the 11th and 14th centuries.

3486. Sampson, J. H. "Sophie Germain and the Theory of Numbers." *Arch. Hist. Exact Sci.* 41 (1990), no. 2, 157–161.

Sophie Germain wrote to Gauss in 1804 giving a result in number theory but it was not until the early 1820s that she made her chief contribution to number theory.

3487. Schinzel, Andrzej. "Progress in Number Theory in the Years 1978–1988". In Polish. *Roczniki Polskiego Towarzystwa Matematycznego. Seria II. Wiadomśći Matematyczne* 29 (1) (1990) 3–10.

This article by a distinguished number theorist discusses in general terms the solution of five important classical problems in number theory during the 1980s.

3488. Schwarz, W. "Zum zahlentheoretischen Werk von Enrico Bombieri". *Jahrbuch Überblicke Mathematik* (1975), 15–151.

On Bombieri's work in number theory.

3489. Schwarz, Wolfgang. "Some Remarks on the History of the Prime Number Theorem from 1896 to 1960." *Development of Mathematics 1900–1950 (Luxembourg, 1992)*, Basel: Birkhäuser, 1994. 565–616.

A comprehensive survey of the history of the prime number theorem and of developments from it. Included are a number of photographs of researchers.

3490. Scriba, Christoph J. "Zur Entwicklung der additiven Zahlentheorie von Fermat bis Jacobi". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 72 (1970), 122–142.

Discusses primarily Fermat, Euler, and C. G. J. Jacobi.

3491. Scriba, Christoph J. *Zur Geschichte der Bestimmung rationaler Punkte auf elliptischen Kurven. Das Problem des Behā-Eddin 'Amuli (Berichte aus den Sitzungen der J. Jungius-Gesellschaft der Wissenschaften, Jg. 1, Heft 6).* Hamburg: Joachim Jungius-Gesellschaft der Wissenschaften, 1984, 52 pp.

A survey of the history of the arithmetic of rational points on elliptic curves from Diophantus to the present. The development is exemplified by an example of Behā-Eddin 'Amūlī (1547–1622), who considered it to be insoluble.

3492. Shedlovskii, A. B. "O rabotakh Chebysceva, P. L. po teorii chisel". *Problemy istorii matematiki i mekhaniki* 1 (1972), 4–9.

Discusses P. L. Chebyshev's work on number theory, including prime numbers and the prime number theorem.

3493. Smith, David Eugene. *A Source Book in Mathematics.* (Source Books in the History of the Sciences, edited by Gregory D. Walcott.) New York: McGraw-Hill, 1929. Reprinted New York: Dover Publications, 1959.

The first 200 pages reproduce in English translations snippets from 24 authors ranging from Treviso's first printed *Arithmetic* of 1478 to selections from Recorde, Steven, Napier, Wallis, Pascal, Euler, Hermite, Gauss, Kummer, Chebyshev, etc. Frequent illustrations.

3494. Smith, H. J. S. *Report on the Theory of Numbers*, originally issued in six parts as a Report of the British Association, 1865. Reprinted in *The Collected Mathematical Papers of H. J. S. Smith* (1895). Also reprinted separately and with the *Mathematical Papers.* New York: Chelsea, 1952 and 1965.

One of the classics, thorough, and full of insight into the mathematics. It is also interesting as a primary source and reflects the considerable learning and skill of the author.

3495. Spalt, Detlef D. "Die mathematischen und philosophischen Grundlagen des Weierstraßschen Zahlbegriffs zwischen Bolzano und Cantor." *Arch. Hist. Exact Sci.* 41 (1991), no. 4, 311–362.

The mathematical and philosophical foundations of the Weierstrassian number concept. Reviewed by J. Dieudonné in **MR** 92e:01048.

3496. Steinig, J. "On Euler's Idoneal Numbers". *Elemente der Mathematik* 21 (1966), 73–88.

3497. Stroyes, J. "Survey of the Arab Contributions to the Theory of Numbers". *Proceedings of the First International Symposium for the History of Arabic Science. Vol. II.* (Papers in European Languages.) Edited by A. Y. al-Hassan, et al. Aleppo, Syria: Institute for the History of Arabic Science, 1978, 173–181.

3498. Uhler, H. S. "A Brief History of the Investigations on Mersenne Numbers and the Latest Immense Primes". *Scripta Mathematica* 18 (1952), 122–131.

3499. Weil, André. *Number Theory. An Approach through History. From Hammurapi to Legendre.* Boston: Birkhäuser Boston, 1984. German edition, *Zahlentheorie. Ein Gang durch die Geschichte. Von Hammurapi bis Legendre.* Boston, Basel, Stuttgart: Birkhäuser, 1992.

A meticulous study by one of the leading mathematicians of his time of texts ranging from the Babylonian tablet known as Plimpton 322 to A. M. Legendre's *Essay on the Theory of Numbers*, Some of the early topics: Euclid's *Elements* (Books 7–9), the Pythagorean theorem and sums of two squares (Babylonia to Vieta), Archimedes' cattle problem and early work on "Pell's" equation, Diophantus, Brahmagupta and Bhaskara. The bulk of the history is devoted to: Fermat, Euler, Lagrange, Legendre, and Euler, The author says that "no specific knowledge is expected of the reader, and it is the author's fond hope that some readers at least will find it possible to get their initiation into number theory by following the itinerary retraced in this book". See the detailed review by Ezra Brown in **MR** 85c:01004. A very useful concordance for Euler's publications on number theory with Weil's book was published by J. J. Burckhardt in *Historia Mathematica* 13 (1986), 28–35.

3500. Willard, D. "Husserl's Essay 'On the Concept of Number' with a Translation of 'On the Concept of Number: Psychological Analysis', by Edmund Husserl (1887)". *Philosophia Mathematica* 9 (1972–1973), 40–52; 10 (1973), 37–87.

The introductory essay is only four pages long, but the translation of Husserl's "Habilitationsschrift" runs to 50 pages.

3501. Willerding, M. F. "Figurate Numbers". *School Science and Mathematics* 72 (1972), 151–158.

Illustrated with tables and diagrams, this article offers an introduction to plane figurate numbers.

3502. Yates, S. "Prime Divisors of Repunits". *Journal of Recreational Mathematics* 8 (1975), 33–37.

Discusses the history, period lengths, and provides a table from $n = 2$ to 100 of prime divisors of $R_n = (10^n - 1)/9$.

3503. Zassenhaus, H., and L. Rüdenberg. *Hermann Minkowski. Briefe an David Hilbert*. Berlin: Springer-Verlag, 1973.

This collection includes letters from Minkowski to Hilbert from 1885 to 1908. Rüdenberg provides reminiscences of her father (Minkowski), and Zassenhaus provides historical background on the Hilbert-Minkowski report on number theory. Well illustrated with portraits of Minkowski's contemporaries, and an annotated index of names.

Fermat's Last Theorem

3504. Edwards, H. "The Background of Kummer's Proof of Fermat's Last Theorem for Regular Primes". *Archive for History of Exact Sciences* 14 (1975), 219–236.

This article questions the tradition that Kummer's proof developed out of an earlier fallacious proof; a previously unknown letter from Liouville to Dirichlet related to this history is given. The author also shows that Kummer's theory of "ideal complex numbers" contained a serious flaw that went unnoticed for ten years. See also the postscript to this paper in the same journal, 17 (1977), 381–394, in which the full text of a manuscript by Kummer, withdrawn from publication in 1844, is transcribed.

3505. Edwards, H. *Fermat's Last Theorem. A Genetic Introduction to Algebraic Number Theory*. New York: Springer-Verlag, 1977. Corrected reprint, Graduate Texts in Mathematics, 50. New York: Springer-Verlag, 1996.

Although this book offers a good deal of historical information, it is meant to be a textbook. Emphasis here is upon Euler, Fermat, Kummer, Kummer's theory of ideal factors, Fermat's Last Theorem for regular primes, determination of the class number, divisor theory for quadratic integers, Gauss's theory of binary quadratic forms, and Dirichlet's class number formula.

3506. Ferguson, R. P. "On Fermat's Last Theorem". *Journal of Undergraduate Mathematics* 6 (1974), 1–14 and 85–97.

Includes tables of Bernoulli numbers and discussion of Fermat's Last Theorem.

3507. Hofmann, Joseph E. "Über eine zahlentheoretische Aufgabe Fermats". *Centaurus* 16 (1972), 169–202.

Determination of Pythagorean triangles whose legs and hypotenuse are square numbers.

3508. Mahoney, Michael Sean. *The Mathematical Career of Pierre de Fermat, 1601–1665.* Princeton, N.J.: Princeton University Press, 1973. Second edition 1994.

A detailed biography of Fermat, with considerable attention given to number theory, as well as other aspects of Fermat's mathematics, his life, and times. Chapter VI is especially relevant for the history of number theory, and is entitled "Between Traditions". It includes such topics as "Numbers, Perfect and Not so Perfect," "Triangles and Squares," "Infinite Descent and the 'Last Theorem,' " etc. See pp. 280–348. See also items 2136.

Reviews: Boyer, C., *Science* (July 13, 1973), 152–153;

Weil, A., *Bulletin of the American Mathematical Society* 79 (1973), 1138–1149.

3509. Mazur, B. "Review of *Ernst Edward Kummer, Collected Papers* (Edited by André Weil)". *Bulletin of the American Mathematical Society* 83 (1971), 976–988.

The review summarizes the main contributions of Kummer to the study of Fermat's Last Theorem, higher reciprocity laws, ideal complex numbers, congruences of p-adic integers, etc.

3510. Noguès, R. *Théorème de Fermat. Son histoire.* Paris: Vuibert, 1932. Review: *Revue Générale des Sciences* 43 (1932), 482.

3511. Ribenboim, P. "The Early History of Fermat's Last Theorem" *The Mathematical Intelligencer* 2 (1976), 7–21.

3512. Singh, Simon. *Fermat's Enigma. The Epic Quest to Solve the World's Greatest Mathematical Problem.* New York: Walker and Company, 1997.

A popular account of the problem and Andrew Wiles's solution. A more technical synopsis of the recent history and its solution (published by Wiles as "Modular Elliptic Curves and Fermat's Last Theorem", *Ann. of Math.* (2) 141 (1995), no. 3, 443–551) is given by Karl Rubin in **MR** 96d:11071.

NUMERICAL ANALYSIS

General Works

3513. Whittaker, Edmund, and G. Robinson. *The Calculus of Observations. A Treatise on Numerical Mathematics.* London and Glasgow: Blackie and Son Limited, 1924.

This classical text book, several times reprinted, emphasizes historical aspects. It could prove a very useful and pleasant introduction to one of the topics of classic numerical analysis.

3514. Faber, Georg. "Übersicht über die Bände 14, 15, 16, 16 der ersten Serie". In *Leonhardi Euleri Opera omnia, I-16-2.* Leipzig and Berlin: Teubner, 1935, vii–cxii.

Useful comments on Euler's works concerning in particular the functions ζ and Γ, Bernoulli numbers, approximations of π, the Euler-Maclaurin formula, trigonometric series, the binomial series, and continued fractions.

3515. Young, David M. "A Survey of Modern Numerical Analysis". *SIAM Review* 15 (1973), 503–523.

A survey of the development of numerical analysis from 1950 to 1970.

3516. Goldstine, Herman H. *A History of Numerical Analysis from the 16th through the 19th Century.* New York, Heidelberg, Berlin: Springer-Verlag, 1977, xiv + 348 pp.

This book is the standard work on the subject, and gives comprehensive treatment to the technical development of numerical analysis during the period when the foundations of the subject were being laid. Beginning with the work of Napier, Briggs, Bürgi, Viète, and Kepler, the early study of logarithms and interpolation leads to a chapter on the Age of Newton, followed by detailed analysis of the contributions of Euler and Lagrange, Laplace, Legendre, and Gauss, with a final chapter on 19th-century figures including C. G. J. Jacobi, Cauchy, and Hermite. Review: Bruins, E. M., *Janus* 65 (1978), 303–312.

3517. Edwards, C. H., Jr. *The Historical Development of the Calculus.* Berlin, Heidelberg, New York: Springer, 1979.

In this clear, expository book the emphasis is on Napier logarithms (chapter 6), the interpolation schema of Wallis for evaluating π and Newton for the binomial series (chapter 7), and expressions for sine and cosine by means of power series (chapter 8).See item 2080.

3518. Nash, Stephen G., ed. *A History of Scientific Computing. Papers from the Conference on the History of Scientific and Numeric Computation held at Princeton University, Princeton, New Jersey, 1987.* (ACM

Press History Series.) New York: Addison-Wesley Publishing Company, 1990.

This collection of papers centers on the scientific computing that has emerged as a separate enterprise only in the last 50 years. Among the different contributions we find one about George Forsythe (linear systems, partial differential equations) and his students, another about Garrett Birkhoff (fluid dynamics); and also papers on the development of ordinary differential equations methods (by C. W. Gear and R. D. Skeel), on the fast Fourier transform (by J. W. Cooley), on the simplex method (by G. B. Dantzig), on the finite elements (by J. T. Oden), on iterative methods (by D. M. Young); as well as numerical analysis in the United Kingdom and numerical linear algebra in Leningrad.

3519. Chabert, Jean-Luc, et al. *Histoire d'Algorithmes. Du caillou à la puce.* Paris: Belin, 1994. English translation by Chris Weeks. *A History of Algorithms. From the Pebble to the Microchip.* Springer, 1999.

This a sort of "source book" for the history of mathematics, but one which offers a different perspective by giving pride of place to algorithms. Thus the titles of many chapters are those of numerical analysis: Newton's Method, Successive Approximations, Linear Systems, Interpolation, Quadratures, Differential Equations, Function Approximation, Acceleration of Convergence.

Approximation of Numbers

3520. Hofmann, Joseph E. "Nicolaus Mercators Logarithmotechnica (1668)". *Deutsche Mathematik.* 3 (1938), 446–466.

For other works dealing with the history of logarithms, see items 3444 and 3446.

3521. Hofmann, Joseph E. "Weiterbildung der logarithmischen Reihe Mercators in England. III". *Deutsche Mathematik* 5 (1940), 358–375.

3522. Naux, C. *Histoire des logarithmes de Neper à Euler.* Paris: A. Blanchard, 1966, 1971. 2 vols.

See item 2086.

3523. Jervis, Jane L. "Vögelin on the comet of 1532: error analysis in the 16th century". *Centaurus* 23 no. 3 (1979/80), 216–229.

This paper shows how Vögelin applied the method of Regiomontanus to determine the distance of comets without taking care of sensitivity to observational errors, and how Tycho Brahe dismissed Regiomontanus treatise.

3524. Grattan-Guinness, I. "Work for the Hairdressers: The Production of de Prony's Logarithmic and Trigonometric Tables". *Annals of the History of Computing* 12 (1990), 177–185.

The description of the mathematical and practical organization by de Prony for production of tables of great accuracy.

3525. Fowler, D. H. "An Approximation Technique, and its Use by Wallis and Taylor". *Archive for History of Exact Sciences* 41 no. 3 (1991), 189–233.

The author examines an approximation technique used by Wallis and Taylor which is often described in terms of continued fractions and shows that neither author really takes this step.

3526. Rivolo, M. T., and A. Simi. "Il calcolo delle Radici Quadrate e Cubiche in Italia da Fibonacci a Bombelli". *Archive for History of Exact Sciences* 52 (1998), 161–193.

Besides several anonymous works, the author examines those of Fibonacci, Gilio di Cecco, Benedetto da Firenze, Canacci, Pacioli, Cardano, Gori, Cataneo, Tartaglia, and Bombelli with respect to the algorithms for quadratic and cubic roots computation.

Approximation of Roots

3527. Runge, C. "Separation und Approximation der Wurzeln". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, IB3a. Leipzig: Teubner, 1898, 404–448.

About roots separation: Descartes, Budan-Fourier, Sturm, and Cauchy; and roots approximation: Newton, Horner, Bernoulli, and Graeffe. See item 5.

3528. Mehmke, R. "Numerisches Rechnen". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, IF. Leipzig: Teubner, 1902, 938–1079.

This article is interesting for the sections about nomography and computation machines. Revised in 1911 by Maurice d' Ocagne in the French edition (article I23). See items 5 and 3535.

3529. Cajori, Florian. "Fourier's improvement of the Newton-Raphson method of approximation anticipated by Mourraille". *Bibliotheca Mathematica* 11 no. 3 (1910), 132–137.

The author examines the most interesting section of Mourraille's "Traité de la résolution des équations en général", those where the difficulties in the process of the Newton-Raphson method are clearly located and removed.

3530. Cajori, Florian. "Horner's Method of Approximation Anticipated by Ruffini". *Bulletin of the American Mathematical Society* 17 (1911), 409–414.

"Ruffini in 1804 elaborated 'Horner's method' of approximation to the roots of numerical equations with a clearness and thoroughness not surpassed in Horner's own exposition of 1819." See item 3538.

3531. Cajori, Florian. "Historical note on the Newton-Raphson method of approximation". *The American Mathematical Monthly* 18 (1911), 29–32.

The author emphasize's that Newton's method of approximation is both distinct from Vieta's method and from those given in our textbooks, whose modern formulation is due to Raphson.

3532. Aaboe, Asger. "Al-Kāshī's iteration method for the determination of sin 1". *Scripta mathematica* 20 (1954), 24–29.

How to solve a cubic equation by successive approximations. (For al-Kāshī's approximate values of π, see item 1366.)

3533. Hamburg, Robin Rider. "The Theory of Equations in the 18th Century: The Work of Joseph Lagrange". *Archive for History of Exact Sciences* 16 (1976), 17–36

Besides his theoretical works on algebraic solutions of polynomial equations, Lagrange did not provide a general theory of numerical solutions. But he consolidated much knowledge on the methods: the number of roots, limits for their values and techniques for approximating them. See item 2450.

3534. Lam Lay-Yong. "The Chinese connection between the Pascal triangle and the solution of numerical equations of any degree". *Historia Mathematica* 7 (1980), 407–424

This paper shows how what we now call the Pascal triangle led the Chinese mathematicians, in the 13th and the beginning of the 14th centuries, to adapt root-extraction procedures to solve numerical equation of any degree.

3535. Evesham, H. A. "Origins and development of nomography". *Annals of the History of Computing* 8 no. 4 (1986), 324–333.

Nomography is the branch of knowledge that uses the results of geometry to carry out computation. This paper describes the development of nomography up to recent results. It particularly focuses on the second half of the 19th century with Lalanne's solution of the cubic equation, Saint-Robert's slide rule, and d'Ocagne's alignment nomogram. See item 3528.

3536. Verley, Jean-Luc. "Techniques de separation de racines au XVIIeme siecle". In *L'à-peu-près. Urbino, 1986.* 1988, 67–77. (Histoire des

Sciences et des Techniques, 3; École des Hautes Études en Sciences Sociales, Paris.)

This paper deals with Newton's technique to separate the roots of an equation, from the "Arithmetica universalis", and with the "Cascade" method in Rolle's "Algebra".

3537. Bailey, D. F. "A Historical Survey of Solution by Functional Iteration". *Mathematics Magazine* 62 (1989), 155–166.

This historical survey deals with functional iterations for computing nth roots or solving numerical equations. Although there is nothing really new, this paper puts together much information and gives many references.

3538. Borowczyk, Jacques. "Sur la vie et l'œuvre de François Budan". *Historia Mathematica* 18 (1991), 129–157.

Among others, the author emphasizes the contributions of Budan to the Budan-Fourier rule and to the Ruffini-Horner algorithm for the resolution of polynomial equations.

3539. Scavo, T. R., and J. B. Thoo "On the Geometry of Halley's Method". *American Mathematical Monthly* 102 no. 5 (1995), 417–426.

Halley's method for solving numerical equations is analogous to Newton's method, but is a third-order method. In this paper we find mathematical reflections as well as historical references.

3540. Ypma, Tjalling J. "Historical Development of the Newton-Raphson Method". *SIAM Review. A Publication of the Society for Industrial and Applied Mathematics* 37 no. 4 (1995), 531–551.

This paper traces the evolution of the Newton-Raphson method. Although not specially original, it is interesting because it provides a sort of review of the contributions of several authors with some extracts: Vieta's method, different methods proposed by Newton, in particular for Kepler's equation, Raphson's formulation, and Simpson's contribution for non-polynomial equations.

Linear Systems

3541. Bauschinger, Julius. "Ausgleichungsrechnung (Methode der kleinsten Quadrate. Fehlertheorie)". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, ID2. Leipzig: Teubner, 1901, 768-798.

An overview of the theory and applications of the least square method. See item 5.

3542. Heinrich, H. "Uber Gauss' Beiträge zur numerischen Mathematik". In

Festakt und Tagung aus Anlass des 200. Geburtstages von Carl Friedrich Gauss (Berlin, 1977). Berlin: Akademie-Verlag, 1978, 109–122.

An overview on Gauss's works on numerical analysis, which emphasizes his remarkable ideas with respect to the need for efficient methods.

3543. Sheynin, O. B. "C. F. Gauss and the Theory of Errors". *Archive for History of Exact Sciences* 20 (1979), 21–72.

Although the focus of this paper is the theory of errors, what is also in question is the least squares method. There are many useful references.

3544. Dorfman, Robert. "The discovery of linear programming". *Annals of the History of Computing* 6 no. 3 (1984), 283–295.

This paper recounts the emergence of the main ideas that constitute linear programming and the roles of the principal contributors, specially those of L. V. Kantorovich, T. C. Koopmans, and G. B. Dantzig.

3545. Lam Lay-Yong, and Ang Tian-Se. "The earliest negative numbers: how they emerged from a solution of simultaneous linear equations". *Archives Internationales d'Histoire des Sciences* 37 (1987), 222–262.

The eighth chapter of the 'Jiu zhang suanshu' gives the earliest general method of solving a system of linear equations. The 'fang cheng' method is very similar to the modern Gaussian elimination which reduces the system to triangular form.

3546. Gauss, C. F. *Theory of the Combination of Observations Least Subject to Errors*. Philadelphia: SIAM, 1995. Translated from Latin by G. W. Steward.

A translation of the second of Gauss's fundamental works on least squares method, with a short afterword which gives a simple overview on the topic.

Interpolation and Approximation of Functions

3547. Burkhardt, H. "Trigonomische Interpolation (mathematische Behandlung periodischer Naturerscheinungen)". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, IIA9a. Leipzig: Teubner, 1904, 642–693.

Lagrange, Bessel, and Le Verrier. See item 5.

3548. Bauschinger, Julius. "Interpolation". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, ID3. Leipzig: Teubner, 1901, 799–820.

Newton, Lagrange, Gauss, Encke, Chebyshev. See item 5.

3549. Turnbull, H. W. "James Gregory: A Study in the Early History of Interpolation". *Proceedings of the Edinburgh Mathematical Society* 3 (1932–1933), 150–172.

The interpolation formula nowadays called the Newton-Gauss formula had been already discovered by Gregory.

3550. Whiteside, Derek Thomas. "Patterns of Mathematical Thought in the later Seventeenth Century". *Archive for History of Exact Sciences* 1 (1960–1962), 179–388.

This essay contains several interesting developments which in particular concern logarithms, interpolation, infinite series and convergence. See item 2073.

3551. Lohne, J. A. "Thomas Harriot als Mathematiker". *Centaurus* 11 (1966), 19–45.

Includes discussion of Harriot's work related to numerical analysis. See also item 2140.

3552. Tucciarone, John. "The Development of the Theory of Summable Divergent Series from 1880 to 1925". *Archive for History of Exact Sciences* 10 (1973), 179–388.

See item 2816.

3553. Elliott, David. "Lagrange interpolation . . . decline and fall?" *International Journal of Mathematical Education in Science and Technology* 10 no. 1 (1979), 1–12.

The author is interested in the different kinds of convergence of Lagrange's interpolation polynomials. The paper recalls the authors who studied this question, from Hermite to Schoenberg, and ends with more recent works, from Erdos to Nevai.

3554. Hewitt, Edwin, and Robert E. Hewitt. "The Gibbs-Wilbraham Phenomenon: An Episode in Fourier Analysis". *Archive for History of Exact Sciences* 21 (1979), 129–160.

See item 2693.

3555. Feigenbaum, L. "Brook Taylor and the method of increments". *Archive for History of Exact Sciences* 34 no. 1-2 (1985), 1–140.

This is an extensive and interesting analysis of Taylor's Methodus incrementorum, which shows the complexity of Taylor series history.

3556. Miel, George. "Of calculations past and present: the Archimedean algorithm". *American Mathematical Monthly* 90 no. 1 (1983), 17–35.

The author goes through different well-known processes for computing π from Archimedes to Descartes, J. Gregory, and Gauss. This is a modern and unified reading to the detriment of the historical reality. On the other hand, this paper gives a global view and allows a better mathematical understanding either before or after reading more historical studies.

3557. Butzer, P. L., M Schmidt, and E. L. Stark. “Observations on the History of Central B-Splines”. *Archive for History of Exact Sciences* 39 no. 2 (1988), 137–156.

Although I. J. Schoenberg may be regarded as the inventor of B-splines in the 1940’s, such functions have already been considered in several publications, particularly in the period 1895-1940. This paper examines in some detail those of Maurer, Lerch, Sommerfeld, Pólya, Brun, and Fränz.

3558. Cooley, James W. “Lanczos and the FFT: A Discovery Before its Time”. In *Proceedings of the Cornelius Lanczos International Centenary Conference (Raleigh, NC, 1993)*. Philadelphia: SIAM, (1994), 3–9.

One may find traces of the FFT algorithm long before Cooley and Tukey’s fundamental paper, in particular in Lanczos’ s works, but also in Gauss’ s Nachlass.

3559. Galuzzi, Massimo. “Lagrange’s essay ‘Recherches sur la manière de former des tables des planètes d’après les seules observations’ ”. *Revue d’Histoire des Mathématiques* 1 no. 2 (1995), 201–233.

It is shown that Lagrange’s essay introduces an algorithm for the approximation of integral series by means of rational functions and polynomials which coincide with Chebyshev polynomials.

Quadrature and Convergence Acceleration

3560. Joyce, D. C. “Survey of Extrapolation Processes in Numerical Analysis”. *SIAM Review* 13 no. 4 (1971), 435–490.

This is a survey of extrapolation processes used to accelerate convergence developed from 1900, particularly in numerical integration and numerical solutions of differential equations. The main interest of this paper is to give an easy overview of the question with many references (350), but it does not give many details on the original works themselves.

3561. Engels, Hermann. “Zur Geschichte der Richardson-extrapolation”. *Historia Mathematica* 6 no. 3 (1979), 280–293.

The author first recalls Richardson’s extrapolation and Romberg’s quadrature. Then he emphasizes Klügel’s *Wörterbuch* (1823) and his use of what is now called the Euler-Maclaurin formula.

3562. Dutka, Jacques. “Richardson extrapolation and Romberg integration”. *Historia Mathematica* 11 no. 1 (1984), 3–21.

Romberg’s integration method is a particular application of Richardson’s extrapolation. But one may trace these methods back to earlier authors : Huygens, Newton, Euler, Maclaurin, and Simpson. The author emphasizes Saigey's works in the 1850s on approximate integration methods.

3563. Piegorsch, Walter W. "Durand's rules for approximate integration". *Historia Mathematica* 16 (1989), 324–333.

This paper considers approximation rules for numerical integration proposed in the later 19th century by the engineer W. F. Durand. This one was more motivated by simplicity than by heightened accuracy.

3564. Tweddle, Ian. "James Stirling's early work on acceleration of convergence". *Archive for History of Exact Sciences* 45 no. 2 (1992), 105–125.

The article contains an English translation of two extracts concerning the acceleration of convergence for slowly convergent series and sequences: the second part of Stirling's paper of 1719 and Proposition 30 of his book *Methodus Differentialis* published in 1730. Moreover, the author clearly explains why the methods work and looks in detail to the examples.

3565. Brezinski, C. "Extrapolation algorithms and Padé approximations: A historical survey". *Applied Numerical Mathematics* 20 (1996), 299–318.

Extrapolation methods for acceleration of convergence and Padé approximants for approximation of functions by rational functions are closely related to continued fractions. While the history of continued fractions begins with Euclid, those of Richardson's process goes back to Huygens in 1654, those of Aitken's process to the Japanese Seki Kowa in 1674, and those of Padé approximants at least to Lambert in 1758. This paper gives a historial overview, until recent times, of both subjects with an extensive bibliography.

Differential Equations

3566. Runge, C., and Fr. A. Willers. "Numerische und graphische Quadratur und Integration gewöhnlicher und partieller Differentialgleichungen". In *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen*, IIC2. Leipzig: Teubner, 1915, 47–176.

This article exposes what was known at the beginning of the century. It includes references to Newton, Cotes, Maclaurin, Gauss, Christoffel, Massau, and Euler for quadrature, and to Runge, Heun, and Kutta for integration. Useful for its extensive references to primary literature of the 18th and 19th centuries.

3567. Collatz, Lothar. *Numerische Behandlung von Differentialgleichungen*. Berlin, Göttingen, Heidelberg: Springer, 1951. 2nd edition, 1955, 3rd ed., 1960. English translation, 1960.

This book is interesting because it presents the state-of-the-art in the first half of the century and has been a reference for a long time.

Moreover, it contains some historical references.

3568. Polak, E. "An Historical Survey of Computational Methods in Optimal Control". *SIAM Review* 15 (1973), 553–584.

A survey of optimal control algorithms with respect to ordinary differential equations, from 1950 to 1970, with many references.

3569. Schlissel, Arthur. "The initial development of the WKB solutions of linear second order ordinary differential equations and their use in the connection problem". *Historia Mathematica* 4 (1977), 183–204.

The history and the prehistory of the approximating solutions given by Wentzel, Kramers, and Brillouin. See item 3240.

3570. Williamson, Frank, Jr. "Richard Courant and the Finite Element Method: A Further Look". *Historia Mathematica* 7 no. 4 (1980), 369–378.

The finite element method is a powerful numerical procedure for solving boundary value problems. Discovered in the 1950s, the method was in fact proposed by Richard Courant in 1943. Moreover, he already mentioned it in the course of a proof in 1922.

3571. Kiro, S. M., and I. V. Chaltseva. "Origin and development of numerical methods for solving the Cauchy problem for ordinary differential equations". *Narisi Istorii Prirodoznavstva i Tekhniki* no. 27 (1981), 3–14, 106.

This is a survey of numerical methods for solving the Cauchy problem, from James Gregory to Collatz.

3572. Hairer, E., S. P. Nørsett, and G. Wanner. *Solving Ordinary Differential Equations I. Nonstiff Problems.* New York: Springer-Verlag, 2nd edition, 1993.

A text book with many really interesting historical commentaries and references.

3573. Zienkiewicz, O. C. "Origins, Milestones and Directions of the Finite Element Method: A Personal View". *Arch. Comput. Methods Engrg.* 2 no. 1 (1995), 1–48.

The finite element method was developed in the aircraft industries in the 1950s. The author traces here, from his own point of view, the steps of its development.

3574. Butcher, J. C., and G. Wanner. "Runge-Kutta methods: some historical notes". *Applied Numerical Mathematics* 22 no. 1-3 (1996), 113–151.

The authors first recall the seminal works of Runge, Heun, Kutta, and Nyström about what is now called the Runge-Kutta methods. Then they give a survey of significant developments of these methods over the last hundred years. There are some other interesting papers in the same issue devoted to the Centenary of Runge-Kutta Methods.

3575. Tournès, Dominique. "L'origine des méthodes multipas pour l'intégration numérique des équations différentielles". *Revue d'Histoire des Mathématiques* 4 no. 1 (1998), 5–72.

The multistep methods may be linked to the Gregory–Newton quadrature formula. They have been invented several times within the context of applied mathematics: first by J. C. Adams as it is well known, then by the astronomer G. H. Darwin to find periodic orbits, by W. F. Sheppard to extend the accuracy of certain mathematical tables, and by C. Störmer to study the aurora borealis. A. Clairaut is also recalled for applying, a century before, the Gregory–Newton formula to solve a differential system on the occasion of the return of Halley's comet.

MATHEMATICAL OPTICS

The list of works below falls under the general head of mathematical optics and includes some works dealing with source-problems. There has been no attempt to differentiate between mathematical and physical optics. Included are general histories of optics as well as samplings of the literature bearing on developments from antiquity to modern times, although the emphasis is on pre-modern optics.

3576. Bork, Alfred M. “Maxwell and the Electromagnetic Wave Equation”. *American Journal of Physics* 35 (1967), 844–849.

Exhibits by way of logical flow charts using modern vectorial notation Maxwell’s three mathematical derivations of the wave equations in electromagnetic theory. See also item 2936.

3577. Boyer, Carl B. *The Rainbow from Myth to Mathematics.* New York and London: Thomas Yoseloff, 1959, 376 pp.

An exhaustive historical survey of the subject from antiquity to the 20th century based on a careful analysis of primary sources. While not neglecting literary-mythical treatments of the rainbow, the author gives major emphasis to the unending quest to devise a mathematical theory accounting for all aspects of this complex phenomenon.

3578. de Broglie, Louis. *Matter and Light. The New Physics.* Translated by W. H. Johnston. London: G. Allen and Unwin; New York: W. W. Norton and Co., 1939. Reprinted New York: Dover Publications, 1946, 1951, 300 pp.

A collection of essays by the Nobel Laureat surveying the 20th-century revolution in physics and its philosophical implications. Focus on the quest for a synthetic view of matter and light consistent with the evidence for both discreteness and continuity at the basis of physical processes. A slightly updated version of the original French edition of 1937.

3579. Bromberg, Joan L. “Maxwell’s Displacement Current and His Theory of Light”. *Archive for History of Exact Sciences* 4 (1967), 218–234.

Shows how Maxwell was led to a generalization of Ampère’s law assigning magnetic effects to displacement as well as to conduction currents. The electromagnetic theory of Maxwell had its origins in this mathematical investigation. See also item 2939.

3580. Buchwald, Jed Z. *The Rise of the Wave Theory of Light.* Chicago: University of Chicago Press, 1989, 474 pp.

3581. Cantor, G. N. "Berkeley, Reid, and the Mathematization of Mid-Eighteenth-Century Optics". *Journal of the History of Ideas* 38 (1977), 429–448.

Characterizes the epistemological debate of the period on the question of whether visual perception of magnitudes and distances rests on an innate geometry of the mind or on experience alone. Initiated by Berkeley, who rejected the geometrical model in favor of perception as a "visual language," the debate bore on the larger issue of how far optics might be reduced to mathematics.

3582. Chappert, André. *Etienne Louis Malus (1775–1812) et la théorie corpusculaire de la lumière*. Paris: Vrin, 1977, 277 pp.

Credits Malus with a major role in the progress of optics despite the fact that shortly after his death the corpuscular theory, on which he based all his optical studies, was superseded by the wave theory. The main support for the argument comes from a consideration of Malus's enduring contributions to geometrical optics, most notably the theorem that bears his name.

3583. Edgerton, Samuel Y. *The Heritage of Giotto's Geometry: Art and Science on the Eve of the Scientific Revolution*. Ithaca, N.Y. and London: Cornell University Press, 1991, 319 pp.

Claims that the development of both perspective (in the artistic sense) and perspectiva (in the optical sense) during the Renaissance led to the modern "view" of space and its geometrical homogeneity. Argues that this way of viewing space allowed for the development of modern diagrammatic techniques and, hence, the dissemination of science through pictorial representation.

3584. Edgerton, Samuel Y., Jr. *The Renaissance Rediscovery of Linear Perpsective*. New York: Basic Books, 1975, 206 pp.

A well-written, informative exposition of the achievement of Brunelleschi and Alberti set against a broad cultural-historical background. The cartographic technique of Ptolemy's *Geography* is shown to have been a major influence in the application of linear perspective to pictorial representation during the Renaissance.

3585. Klein, Martin J. "Einstein's First Paper on Quanta". *The Natural Philosopher* 2 (1963), 59–86.

A critical analysis of the revolutionary paper of 1905 proposing the photon conception of light. Klein argues that the light quantum hypothesis was rooted, not in Planck's theory of black-body radiation, but rather in Einstein's own profound studies of thermodynamics and statistical mechanics.

3586. Knorr, Wilbur. "Archimedes and the Pseudo-Euclidean *Catoptrics*: Early Stages in the Ancient Geometric Theory of Mirrors". *Archives internationales d'histoire des sciences* 35 (1985), 27-105.

Calls into question the traditional narrative of the early development of mathematical optics on the basis of a reinterpretation of certain key sources and their attributions. An extremely tendentious but important work.

3587. Knorr, Wilbur. "Pseudo-Euclidean Reflections in Ancient Optics". *Physis* 31 (1994), 1–45.

A basic refutation of Heiberg's claims about the inauthenticity of the *Optics* and *Catoptrics* attributed to Euclid.

3588. Lejeune, Albert. *Euclid et Ptolémée. Deux stades de l'optique géométrique grecque*. Louvain: Bibliothèque de l'université, 1948, 196 pp.

Focuses on the theory of vision set out by Ptolemy in the first three books of the *Optics*. With Ptolemy, Lejeune argues, optics found its proper method, abandoning the strictly geometrical, axiomatic procedure of Euclid in favor of a more broadly based approach that included physical and psychological as well as mathematical components.

3589. Lejeune, Albert. "Recherches sur la catoptrique grecque d'après les sources antiques et médiévales". *Académie royale de Belgique, Classe des lettres et des sciences morales et politiques, Mémoires (Brussels)*, 52 (2) (1957), 199 pp.

Sequel to the author's *Euclide et Ptolémée*, in which the principal subject is the treatment of reflection and refraction in the later books of Ptolemy's *Optics*. For a fuller understanding of Ptolemy's work Lejeune discusses contributions to catoptrics by other ancient Greeks, Euclid, Archimedes, Hero of Alexandria, and the pseudo-Euclid.

3590. Lindberg, David C. *Theories of Vision from al-Kindi to Kepler*. Chicago and London: University of Chicago Press, 1977, 324 pp.

Argues that Kepler's theory of the retinal image, the first successful solution to the problem of vision, was the culminating achievement of the medieval *perspectiva* tradition. The tradition combined two major approaches to optics carried over from antiquity, the mathematical (Euclid) and the physical and psychological (Aristotle and Galen). Extensive bibliography.

3591. Mach, Ernst. *The Principles of Physical Optics: An Historical and Philosophical Treatment*. Translated by John S. Anderson, and A. F. A. Young. New York: E. P. Dutton and Co., 1925; London:

Methuen and Co., 1926. Reprinted New York: Dover Publications, c. 1953, 324 pp.

Sets forth in a topical arrangement the fundamental concepts of optics and the historical threads in their development. Mathematical derivations and experimental results bulk large in an account that proposes to free optical principles of their "metaphysical ballast." Published originally in German in 1921, the work excludes "radiation, the decline of the emission theory of light, Maxwell's theory, together with relativity," subjects Mach intended to treat in a sequel.

3592. Malet, Antoni. "Keplerian Illusions: Geometrical Pictures vs Optical Images in Kepler's Visual Theory". *Studies in History and Philosophy of Science* 21 (1990), 1–40.

Argues that it was not until well after Kepler that European optical thinkers transformed optical images from fundamentally subjective entities to fundamentally objective, physically-generated entities.

3593. Park, David. *The Fire within the Eye: A Historical Essay on the Nature and Meaning of Light.* Princeton, N.J.: Princeton University Press, 1997, 377 pp.

A useful general introduction to the history of optics taken in a broad way to include ideas not just about the physical status of light and color but also about the problems of visual perception and its psychological basis. Supersedes its closest rival, Vasco Ronchi's *The Nature of Light.* See item 3596.

3594. Rashed, Roshdi. "A Pioneer in Anaclastics: Ibn Sahl On Burning Mirrors". *Isis* 81 (1990), 464–491.

Demonstrates that the tenth-century Arab mathematician, Ibn Sahl, knew the law of refraction and was able to apply it to the analysis of burning lenses.

3595. Ronchi, Vasco. "Classical Optics Is a Mathematical Science". *Archive for History of Exact Sciences* 1 (1960–1962), 160–171.

Argues that the modern study of images produced by lenses and mirrors is not, as is generally thought, a physical science based on observation and experiment but rather a mathematical science grounded on inferences logically drawn from an assumed hypothesis, to wit, Kepler's conception of the eye's distance-measuring triangle. The failure to recognize Kepler's idea for what it is, a mere working hypothesis to be modified or rejected as experiments dictate, has drawn attention away from serious discrepancies between the theory of images and observed phenomena.

3596. Ronchi, Vasco. *The Nature of Light. An Historical Survey.* Translated by V. Barocas Cambridge, Mass.: Harvard University Press, 1970, 288 pp.

Surveys ideas on the nature of light from Greek antiquity to the middle of the 19th century. Calls attention to the difficulties experienced historically in distinguishing between light as an external reality and light as a subjective sensation and to the attendant problems in developing a proper science of photometrics. An expansion of the original Italian edition of 1939. This work has been superseded by that by David Park, item 3593.

3597. Sabra, A. I. "Ibn al-Haytham's Criticisms of Ptolemy's *Optics*". *Journal of the History of Philosophy* 4 (1966), 145-149.

Shows not only that Ibn al-Haytham had a deep familiarity with Ptolemy's optical work but that he had subjected it to close and critical scrutiny, thus finding some of Ptolemy's positions to be inadequate or incoherent.

3598. Sabra, A. I. *Theories of Light from Descartes to Newton.* London: Oldbourne, 1967, 363 pp. .

Not a survey but a study of "problems and controversies. . .particularly important in the development of seventeenth-century theories about the nature of light and its properties." In this period, which embraced the contributions of Fermat, Huygens, Hooke, and Pardies as well as those of Descartes and Newton, a mathematical-experimental investigation of refraction (and its application to dispersion by Newton) was a central concern.

3599. Sabra, A. I. "Ibn al-Haytham's Lemmas for Solving Alhazen's Problem". *Archive for History of Exact Sciences* 26 (1982), 299-324.

A technical discussion of Alhazen's solution to the problem of finding the point of reflection from any spherical convex or concave mirror when a center of sight and a point-object are given.

3600. Sabra, A. I. "Psychology versus Mathematics: Ptolemy and Alhazen on the Moon Illusion." In *Mathematics and its Applications to Science and Natural Philosophy in the Middle Ages: Essays in Honor of Marshall Clagett*. Edited by Edward Grant, and John Murdoch. Cambridge: Cambridge University Press, 1987. 217-247.

Based on close textual study, this article brings to sharp contrast Ptolemy's and Alhazen's efforts to explain the Moon Illusion, showing in particular how dependent Alhazen's explanation was upon psychological rather than physical factors.

3601. Shapiro, Alan E. *Fits, Passions, and Paroxysms: Physics, Method, and Chemistry and Newton's Theories of Colored Bodies and Fits of Easy Reflection.* Cambridge: Cambridge University Press, 1993. 400 pp.

3602. Simon, Gérard. *Le regard, l'être et l'apparence dans l'Optique de l'antiquité*. Paris: Seuil, 1988. 216 pp.

Shows that the focus of Ptolemy's optical analysis is upon visual perception, not the physics of light and that to understand that focus otherwise is to misunderstand the resulting ray-analysis completely.

3603. A. Mark Smith, tr. *Ptolemy's Theory of Visual Perception: An English Translation of the Optics with Introduction and Commentary.* (Transactions of the American Philosophical Society, 86.2.) Philadelphia: American Philosophical Society, 1996. 300 pp.

Aside from an English translation, this work includes a relatively extensive discussion of the mathematical and historical implications of Ptolemy's *Optics*.

3604. Smith, A. Mark. "Extremal Principles in Ancient and Medieval Optics". *Physis* 31 (1994), 113-140.

Shows how the ray-concept changed fundamentally between antiquity and the Middle Ages because of the way the ray was understood to exemplify the principle of natural economy–from an economy of distance (shortest path) to an economy of effort (least action).

3605. Smith, A. Mark. "Ptolemy, Alhazen, and Kepler and the Problem of Optical Images". *Arabic Sciences and Philosophy* 8 (1998). 1-36.

The failure of pre-Keplerian optical thinkers to properly analyze image-formation in lenses was due not to methodological shortcomings but to fundamental conceptual constraints. Kepler's analysis of the crystalline lens as a mere focusing device for retinal images thus represents a sharper break with the Perspectivist theoretical tradition than Lindberg allows in his 1977 study. See item 3590.

3606. Steffens, Henry John. *The Development of Newtonian Optics in England*. New York: Science History Publications, 1977, 190 pp.

Characterizes Newtonian optics as a coherent, comprehensive system of scientific description and explanation distinct both from Newton's optics, which inspired it, and from the wave theory of the early 19th century, which supplanted it. The Newtonians approached optics as a quantitative study of the dynamics of light corpuscles.

3607. Synge, J. L. *Geometrical Optics. An Introduction to Hamilton's Method*. Cambridge: Cambridge University Press, 1962, 110 pp.

A concise exposition of Hamilton's generalized mathematical approach to optics by one of the editors of his optical papers. This little text first appeared in 1937.

3608. Takahashi, Ken'ichi. *The Medieval Latin Traditions of Euclid's Catoptrica*. Fukuoka: Kyushu University Press, 1992, 371 pp.

Includes a useful discussion of the Greek tradition of this work as well as an attempt to understand some of the more puzzling axiomatic features of Euclid's reflection-analysis.

3609. Verdet, Emile. "Introduction" to *Oeuvres complètes d'Augustin Fresnel*. Edited by Henri de Senarmont, Emile Verdet, and Léonor Fresnel. Paris: Imprimerie Impériale, 1866–1870. 3 vols.

A detailed, critical analysis of the work of the French physicist, whose mathematical skills played a major role in the establishment of the wave theory of light and its triumph over the corpuscular theory.

3610. Westfall, Richard S. "The Development of Newton's Theory of Color". *Isis* 53 (1962), 339–358.

Argues that Newton's theory of color, although it presupposed a mechanistic framework, was a revolutionary break with the views of Aristotelians and mechanists alike, both schools regarding colors essentially as "modifications of pure light by the admixture of darkness." By associating specific colors with specific kinds of rays, each displaying its own characteristic degree of refrangibility, Newton made the study of colors a mathematical science for the first time.

3611. Whittaker, Sir Edmund Taylor. *A History of the Theories of Aether and Electricity.* London: Thomas Nelson & Sons, 1951–1953. Reprinted New York: Harper & Brothers, Harper Torchbooks, 2 vols. 1960, 434 pp.; 319 pp.

A detailed, authoritative work, broader in subject matter than its title suggests and covering the period from Descartes and Newton through the first quarter of the twentieth century. Relative to mathematical optics it is particularly valuable for its treatment of the many models of the "luminiferous aether" called forth by the wave theory. See also items 3016, 3746.

3612. Wilde, Emil. *Geschichte der Optik vom Ursprunge dieser Wissenschaft bis auf die gegenwärtige Zeit.* 2 vols. 1838–1843. Reprinted Wiesbaden: Dr. Martin Sändig, 1968, 352 pp.; 407 pp. 2 vols. in 1.

Provides useful, if dated, accounts of the most important writers on optics from Greek antiquity through the 18th century. Almost 250 pages devoted to Newton and his critics, among whom Goethe receives the most extensive treatment. Mathematical derivations and proofs of the optical laws under discussion. A separate chapter on caustics, rarely considered in standard histories of optics.

POTENTIAL THEORY

The entries listed below are intended to provide access to the whole range of literature on potential theory from 1680 to 1950, with emphasis on the classical period, 1800 to 1900. No attempt has been made at a comprehensive listing here, but the choice of histories (Todhunter, Bacharach, Heinrich Burkhardt and Meyer, Sologub) and of texts (Betti, Boussinesq, Clausius, Kellogg, de la Vallée Poussin, Mathieu, Neumann, Riemann) has been guided by the desire to provide such a listing indirectly. The other principle behind this selection is the need for correction: the older histories and texts omit material, they repeat erroneous claims, they cannot be updated as they would be in the world of Orwell's *1984*. So a sprinkling of important articles by Chasles, Vallée-Poussin, and Poincaré has been included in the spirit of Kenneth May.

Original Works

3613. Betti, Enrico. *Lehrbuch der Potentialtheorie und ihrer Anwendungen auf Elektrostatik und Magnetismus, von Enrico Betti.* Autorisierte deutsche Aufgabe. Besorgt, und mit Zusätzen, sowie einen Vorwort versehen von W. Franz Meyer. Stuttgart: W. Kohlhammer, 1885, xv + 434 pp.

Originally three articles in the *Nuovo cimento* in 1863–1864, then a greatly expanded book, *Teorica della forze che agiscono secondo la legge di Newton, e sua applicazione alla elettricità statica* (Pisa, 1865), quickly translated into German, this material on gravity, electrostatics, magnetism, and their potentials became very influential on the Continent in the period 1880–1900, since it was well presented, easy to read, and accurate. The original articles are reprinted in the *Opere matematiche di Enrico Betti, t. 2* (Milan: Hoepli, 1913).

3614. Boussinesq, Valentin Joseph. *Application des potentiels à l'étude de l'équilibre et du mouvement des solides élastiques, avec des notes étendues sur divers points de physique mathématique et d'analyse.* Paris: Gauthier-Villars, 1885, 722 pp.

Applications are in elasticity, fluid mechanics, heat, waves, in two and three dimensions, including bending of plates. This complements Bacharach and Mathieu, as it lays emphasis on French contributions, almost exclusively *not* in gravitation, electricity, and magnetism (for which, see Mathieu, item 3625).

3615. Chasles, Michel. "Enoncé de deux théorèmes généraux sur l'attraction des corps et la théorie de la chaleur". *Comptes rendus de l'Académie des Sciences de Paris* 8 (1839), 209–211.

The apperance of this paper caused the deluge of articles on potential theory from 1840 to 1895. It announced the conjectured theorem that a given amount of mass may be spread on a given surface in infinitely many ways such that the potential is constant inside the surface and equal to a certain potential outside the surface, i.e., that various distributions can produce the same potential. This theorem was seemingly refuted by Gauss in 1840, but was proved by Poincaré in 1896 and Frostman in 1935.

3616. Clausius, Rudolf Julius Emmanuel. *Die Potentialfunktion und das Potential: ein Beitrag zur mathematischen Physik*. Leipzig: Barth, 1859, vi + 108 pp. 2nd ed., 1877, x + 178 pp.

This small, oft-quoted text represents the watershed between the older presentations of Franz Neumann and Dirichlet (following Gauss) and the new age of Carl Neumann and Riemann (following Green). References are few. Apart from the usual theorems and the calculation of potential functions for bodies of various special shapes, the last third of the book deals with the potential of systems of masses, or their (potential) energy, and the relation of energy to motion (1877 edition).

3617. Gauss, Carl Friedrich. "Theoria attractionis corporum spheroïdicorum ellipticorum homogeneorum methodo nova tractata". *Commentationes recentiores Societatis regiae scientiarum Gottingensis* 2 (1813), 1–24, bound in the volume as number 9 or 10. Read 18 Mart. 1813.

This classic paper contains a trivial version of the divergence theorem involving no derivatives in the surface integral, all of which integrals are zero, so that no volume integral is involved. It also contains results on the attractions of ellipsoids already derived by Ivory (1809), where the attraction is calculated by reducing the problem for internal and external points for the given ellipsoid to the problem of finding the attraction of a point on the surface of another ellipsoid. Involved are integrals with discontinuous values as to whether a point is inside, on, or outside a surface.

3618. Gauss, Carl Friedrich. "Allgemeine Lehrsätze in Beziehung auf die in verkehrten Verhältnisse des Quadrats der Entfernung wirkenden Anziehungs- und Abstossungs-kräfte". *Resultate aus den Beobachtungen des magnetischen Vereins im Jahre 1839*. Herausgegeben von C. F. Gauss and W. Weber. Leipzig: Weidmannsche Buchhandlung und Verlag, 1840, 1–51.

The major theorem of this paper, the reason why it was written, and a theorem repeatedly stated by Gauss to be true and to be proved rigorously, directly contradicts Chasles's conjecture of 1839. However, Gauss's theorem is false; he attempted to prove it by varying the mass distribution. Despite this error, this is an extraordinarily rich paper, containing surface distributions (not just thin layers) for the first time. This presentation, somewhat pre-Green in treatment, is repeated by Dirichlet, Clausius, Riemann, and Franz Neumann. The change away from it comes with Carl Neumann and his extensive use of Green's work.

3619. Green, George. *Mathematical Papers of George Green.* Edited by N. M. Ferrers. London: Macmillan, 1871. Reprinted New York: Chelsea Publishing Co., 1970, xii + 336 pp.

This volume contains all Green's published works including the *Essay* (pp. 1–115). Many other treasures await the diligent reader: prepotentials, applied Lie groups, the theory of elasticity with a potential, etc.

3620. Green, George. *An Essay on the Application of Mathematical Analysis to the Theories of Electricity and Magnetism.* Nottingham: Printed for the author by T. Wheelhouse, 1828, ix + 72 pp.

This *Essay* really needs no comment, since its contents are well known—the potential, the various formulae (but not the so-called Green's theorem for the plane), the mean value theorem for harmonic functions, the Green's function, the interior and exterior forms of the so-called Dirichlet problem for one or more closed surfaces. First referred to in other literature in 1835, it was brought into prominence by Thomson in 1845, then reprinted by Crelle in three parts in 1850–1855, and thereafter universally developed and applied.

3621. Hilbert, David. "Ueber das Dirichlet'sche Princip". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 8 (1899), 184–188.

This note announces a new *hope* for proving the Dirichlet principle in general, but contains no proof; the essence lies in two simple examples of the principle which is enunciated in a very general form.

3622. Hilbert, David. "Ueber das Dirichlet'sche Princip". *Festschrift zur Feier des 150-jährigen Bestehens der Königlichen Gesellschaft der Wissenscahften zu Göttingen. Abhandlungen der mathematisch-physikalischen Klasse.* Berlin: Weidmannsche Buchhandlung, 1901, 1–27.

The proof of the Dirichlet principle in general form, for Riemann surfaces, with the appropriate, requisite boundary values. Reprinted in *Mathematische Annalen* 59 (1904), 161–186.

3623. Kellogg, Oliver Dimon. *Foundations of Potential Theory.* Berlin: Springer, 1929. Reprinted New York: Dover, 1953, ix + 384 pp.

This classic text is not couched in measure theory terms and is one of the last in the Green-Dirichlet-Riemann tradition. It is a comprehensive, detailed, and documented work with several hundred references in its footnotes.

3624. Vallée-Poussin, Charles-Jean-Gustave-Nicolas de la. *Le potentiel logarithmique. Balayage et représentation conforme.* Louvain: Librairie universitaire; Paris: Gauthier-Villars, 1949, xii + 452 pp.

This text is a work born ten years after its time; it is limited to extending the author's prewar results in potential theory, together with a systematic and historical treatment of the topic. References are few. Certainly there are new ideas: extensions of the ideas of distribution and capacitary potential, and complete sets. But the war prevented any new research results from flowing into Belgium after 1939; so, a picture of potential theory as it was, with a little glimpse towards the future. It is one of the first texts couched in terms of measure theory.

3625. Mathieu, Emile Léonard. *Théorie du potentiel et ses applications à l'électrostatique et au magnétisme. Première partie: Théorie du potentiel. Seconde partie: Électrostatique et magnétisme.* Paris: Gauthier-Villars, 1885 and 1886. *Traité de physique mathématique*, t. III et IV, vi + 179 pp. and vi + 235 pp., respectively.

These two texts cover that half of potential theory and its applications not covered by Boussinesq. References are few. The first part contains the theorems of potential theory, expressed in terms of both attraction between masses and heat conduction; one-third of this part is devoted to bodies composed of thin layers whose boundary surfaces are level surfaces for the potential. The second part applies the potential to electro- and magnetostatics.

3626. Neumann, Carl Gottfried. *Das Dirichlet'sche Prinzip in seiner Anwendung auf die Riemann'schen Flächen.* Leipzig: Teubner, 1865, 80 pp.

This, together with his *Vorlesungen über Riemann's Theorie der Abel'schen Integrale* (Leipzig: Teubner, 1865), marks the beginning of Neumann's long *affaire* with the Dirichlet principle, the Dirichlet problem, and their proofs. Here functions of a complex variable are used to map the Riemann surface or sphere to the plane, under various boundary conditions including prescribed discontinuities on the boundary of the polygonal region corresponding to the surface. The modern version of this work is in Hermann Weyl's *Der Idee der Riemannschen Fläche* (Leipzig, Berlin: Teubner, 1913).

3627. Neumann, Carl Gottfried. *Untersuchungen über das logarithmische und Newton'sche Potential.* Leipzig: Teubner, 1877, xvi + 368 pp.

The most quoted work in the field codifies nearly 20 years of his work. References do not abound, because most of the work is new, generalizing all his own previous work as well as that of others. It is characterized by order, discipline, and system, attempting to *prove* where Green, Gauss, and Dirichlet had only *sketched*, to fill in gaps in arguments or to create new methods of proof. The detailed contents are now classical: elementary potential theory; distributions of mass, charge; double distributions or doublets; the use of the method of arithmetic means to establish the existence of a solution to the first boundary value problem for *convex* surfaces (avoiding the Dirichlet principle error). His attempts, from 1860 to 1887, to prove Dirichlet's principle for *general* surfaces, were fruitless, much to his despair.

3628. Neumann, Carl Gottfried. "Ueber die Integration der partiellen Differentialgleichung: $\partial^2\phi/\partial x^2 + \partial^2\phi/\partial y^2 = 0$". *Journal für die reine und angewandte Mathematik* 59 (1861), 335–366.

This paper initiated the strict solution of the first boundary value problem for the plane for Laplace's equation, the stationary (time-independent) temperature distribution in a homogeneous body under Fourier's model of heat conduction, with values for the temperature specified on the boundary of the domain. The problem is physically reformulated in terms of the potential of a mass distribution. Neumann then immediately follows Green's example, giving auxiliary results and introducing the symmetric Green's function. Solutions of the problem are found for specific boundaries and the appropriate Green's functions are calculated.

3629. Neumann, Carl Gottfried. "Zur Theorie des logarithmischen und des Newtonschen Potentials". *Mathematische Annalen* 11 (1877), 558–566.

Neumann solves the Dirichlet problem in the plane by the method of the arithmetic mean as applied to general plane domains bounded by convex curves with continuous curvature. The presentation is designedly independent of any specially chosen coordinate system. This article is a reprint of an article of the same title in the *Berichte über die Verhandlungen der mathematisch-physikalischen Classe der Königlichen Sächsischen Akademie der Wissenschaften zu Leipzig* 22 (1870), 49–56 and 264–321.

3630. Neumann, Ernst Richard Julius. *Studien über die Methoden von C. Neumann and G. Robin zur Lösung der beiden Randwertaufgaben der Potentialtheorie*. (Preisschriften gekrönt und herausgegeben von der Fürstlich Jablonowski'schen Gesellschaft, Nr 37.) Leipzig: Teubner, 1905, xxiii + 194 pp.

A prize-essay written to unify and complete the researches of the period 1870 to 1900, particularly those of Poincaré (1896) and Carl Neumann (1870). Besides these two, references are made only to Robin, Liapunov, and Schwarz. Proofs are presented for the first two boundary value problems in three dimensions (the plane case is said to be "similar"); these proofs cover convergence of the Neumann and Robin sequences of potentials. Two features stand out: Liapunov's normal derivatives and the polar function (Green's function is the sum of a series of polar functions derived from the arithmetic mean process).

3631. Ostrogradskii, Mikhail Vasil′evich. "Note sur la théorie de la chaleur" and "Deuxième note sur la théorie de la chaleur". *Mémoires de l'Académie*

Impériale des Sciences de Saint Pétersbourg (1831), 129–138 and 123–126 [sic].

The material contained in these notes dates from 1826 when it was first read to the Paris Academy. It is therefore almost simultaneous with George Green's *Essay.* The divergence theorem is explicit and for arbitrary surfaces in three-dimensional space; hence it has the same applicability as Gauss's version of 1813 and Green's formulae. Further, and maybe more importantly, the theorem is developed for rational entire functions of differential operators. These notes, especially the first, have been vastly neglected and underrated.

3632. Poincaré, Jules Henri. "La méthode de Neumann et le problème de Dirichlet". *Acta Mathematica* 20 (1896), 59–142.

First announced in the *Comptes rendus de l'Académie des Sciences de Paris* 120 (1895), 347–352, séance du 18 février 1895. This gives a rigorous proof that the Dirichlet problem has a solution for simply connected singularity-free surfaces, *convex or not.* It suggests, but only with physical arguments, that there are an infinity of potentials, the *fundamental functions*, corresponding to simple distributions on the surface, these functions being mutually orthogonal and satisfying a normal-derivative discontinuity at the surface, and providing for series expansions of all potentials.

3633. Poincaré, Jules Henri. "Sur les équations aux dérivées partielles de la physique mathématique". *American Journal of Mathematics* 12 (1890), 211–294.

Here is the *méthode de balayage*, the method of sweeping out mass from space onto a given surface. The method dates back to Poisson and Chasles; it gives a unique potential but not a unique mass distribution due to the selection process involved; the existence of the potential is proved rigorously. Poincaré proves by physical arguments, which he expected could be made rigorous and suggested how, that there is a sequence of fundamental functions, mutually orthogonal, which will solve a sequence of boundary value problems and so provide a series for the potential.

3634. Poisson, Siméon-Denis. "Mémoire sur la distribution de l'électricité à la surface des corps conducteurs". *Mémoires de la Classe des Sciences mathématiques et physiques de l'Institut* 12 (Première partie, année 1811) (1812), 1–92. Lu les 9 mai et 3 août 1812.

Poisson discusses spheres and surfaces not much different from spheres, both alone or in pairs. He rederives what he twice states is Laplace's result on the distribution of a thin layer of mass or charge on a surface such that the distribution exerts no force inside the surface; in making clear Laplace's argument he shows that the force suffers a jump discontinuity in the direction normal to the surface and that this jump is proportional to the density of the distribution.

3635. Poisson, Siméon-Denis. "Second mémoire sur la distribution de l'électricité à la surface des corps conducteurs". *Mémoires de la Classe des Sciences mathématiques et physiques de l'Institut* 12 (Seconde partie, année 1811) (1814), 163–274. Lu le 6 septembre 1813.

Ostensibly about calculating charge densities or distributions on electrified surfaces (in his terms, the thickness of the charge layer), Poisson actually writes about series, the summation and convergence thereof, and about definite integrals: the Poisson integral forms a major part of this study.

3636. Riemann, Georg Friedrich Bernhard, and Karl Friedrich Wilhelm Hattendorf. *Schwere, Elektricität und Magnetismus nach den Vorlesungen von Bernhard Riemann (Göttingen 1861).* Hannover: Carl Rümpler, 1876. Reprinted 1880, x + 358 pp.

This text dates from Riemann's lectures of 1861. References are few. The presentation breaks away from the Gauss-Dirichlet tradition since Green's work is heavily used. It is bedevilled by the German distinction between the *potential function* (attraction of a body on a mass point) and the *potential* (the internal energy of a system), a distinction stemming from a priority question on the use of the word "potential" (Gauss, Green). Green's function and its symmetry properties are used, together with Dirichlet's principle and its then standard "proof." Half the book is on potential theory, half on applications to the major interests of the Göttingen *magnetischer Verein* and Weber: electrostatics, direct and alternating currents, magnetism, electromagnetism, electrodynamics, and the earth's magnetism.

3637. Robin, Victor Gustave. "Sur la distribution d'électricité à la surface des conducteurs fermes et des conducteurs ouvertes". *Annales de l'École normal supérieure* 3 (1886, Supplément), 58 pp.

This paper is Robin's thesis, and contains both the statement of Robin's problem (distribution of charge on a regular surface so that the potential is constant on the surface) and a method for solving it.

3638. Robin, Victor Gustave. *Oeuvres scientifiques, réunies et publiées sous les auspices du ministère de l'Instruction publique, par Louis Raffy.* Paris: Gauthier-Villars, 1899–1903. 3 vols: I. *Théorie nouvelle des fonctions, exclusivement fondée sur l'idée de nombre* (1903), vi + 215 pp.; II, première partie. *Physique mathématique* (1899), vi + 150 pp.; II, seconde partie. *Thermodynamique générale* (1901), xvi + 271 pp.; III. *Leçons de chimie physique.*

Théorie nouvelle des fonctions does calculus without "les pretendus nombres irrationels" in the tradition of Kronecker and the later work of E. Borel; these lectures were given in 1892–1893 at the Faculté des Sciences. *Physique mathématique* contains all his published papers as well as some manuscript notes on the same topics. *Thermodynamique générale* covers his course on the foundations of chemistry given in 1896 and has been fully reedited by Raffy. The third volume was never published.

3639. Schwarz, Carl Hermann Amandus. “Ueber einen Grenzübergang durch alternierendes verfahren”. *Vierteljahresschrift der naturforschen Gesellschaft zu Zürich* 15 (1870), 272–286.

The existence of a solution to the Laplace equation is established by solving the boundary value problem for one domain of the plane where it can be solved and hence completing the boundary values for another domain; the new boundary value problem for the second domain is solved and this completes a new set of boundary values for the first domain. Thus one forms sequences of solutions on each domain which converge to a single solution on the union of the two domains, where both the sequences agree on the intersections in the limit, as, for example, on the nonempty intersection of a circle and a square. No assumption of continuity, curvature, or convexity on the boundary is required, but the domain must be built up as the union of domains where the problem can be solved already. This paper is reprinted on pp. 133–143 of Band 2 of his *Gesammelte mathematische Abhandlungen*.

3640. Schwarz, Carl Hermann Amandus. *Gesammelte mathematische Abhandlungen von H. A. Schwarz.* Berlin: Springer, 1890. 2 Bände. Reprinted New York: Chelsea Publishing Co., 1972, as 2 vols. in 1, xiv + 338 pp. and vii + 370 pp.

This is by far the easiest method of access to Schwarz's work, particularly that of 1870–1872 on the integration of Laplace's equation in the plane, for circles and other amenable geometric shapes (see especially pp. 144–210 of Band 2).

3641. Sologub, Vladimir Stepanovich. *Razvitie teorii ellipticheskikh uravnenii v XVIII i XIX stoletiyakh* (†Development of the theory of elliptic equations in the 18th and 19th centuries†). Akademiia Nauk Ukrainskoi SSR, Sektor istorii estestvoznaniia i tekhniki, Institut istorii. Kiev: Naukova dumka, 1975, 280 pp. In Russian.

This work attempts a synthesis of the theory, motivation, and major results for elliptic equations and their boundary value problems, and to fill in the gaps left by Todhunter, Bacharach, and Heinrich Burkhardt and Meyer. There are over 370 references, almost all to original papers and monographs. Despite the author's undoubted expertise and valiant efforts, there are flaws in his synthesis: major papers of Chasles and Hilbert are not mentioned, and the guiding hand of La Vallée-Poussin is sorely missed. Such faults may be ignored in an undertaking of such vast scale, as the coverage is 1750 to 1900, in detail. This work deserves to be better known.

3642. Thomson, William. “Note sur une équation aux différences partielles, qui se présente dans plusieurs questions de physique mathématique”. *Journal de mathématiques pures et appliquées* 12 (1847), 493–496.

Here is the so-called Dirichlet principle in print, with variation of the function, some five to ten years before Riemann.

Historical Studies

3643. Archibald, Thomas. “Tension and Potential from Ohm to Kirchhoff”. *Centaurus* 31 (1988), no. 2, 141–163.

Gives a detailed examination of the conceptual framework employed by Ohm in the formulation of Ohm’s law and the reinterpretation by Kirchhoff in terms of potentials.

3644. Archibald, Thomas. “From Attraction Theory to Existence Proofs: The Evolution of Potential-Theoretic Methods in the Study of Boundary-Value Problems, 1860–1890”. *Rev. Histoire Math.* 2 (1996), no. 1, 67–93.

Discusses the transition of potential theory from a branch of mathematical physics to a branch of pure mathematics as represented in the works of Carl Neumann, Hermann Amandus Schwarz, and Émile Picard.

3645. Bacharach, Max. *Abriss der Geschichte der Potentialtheorie*. Wurzburg: Sturtz Druckerei, 1883, 78 pp.

This doctoral thesis is a summary of the history of potential theory and is equally as valuable as Todhunter. There are over 350 references; all the main issues are treated (not always correctly: see the Gauss-Chasles-Poincaré controversy); a long list of contemporary applications, mainly in electricity and magnetism, are cited though not always evaluated. The work of George Green is featured, probably through Carl Neumann’s influence, and is given equal prominence with that of Gauss. The best coverage is for the period 1825 to 1880.

3646. Bowley, R. M., et al. *George Green: Miller, Snienton*. Nottingham: Nottingham Castle, 1976, 96 pp.

This small book gives an excellent life of Green, as well as a valuable set of letters spanning his academic career. See also item 2938.

3647. Burkhardt, Heinrich, and W. F. Meyer. “Potentialtheorie”. *Encyklopädie der mathematischen Wissenschaften mit Einschluss ihrer Anwendungen, II.A7b.* Leipzig: B. G. Teubner, 1900, 464–503.

This article gives a synopsis of potential theory from Lagrange to Hilbert. There are over 300 references. The presentation is systematic and critical as well as historico-didactic. It covers definitions of the potential, plane and three-dimensional potentials, the contributions of Green, Gauss, and Thomson, and the various principles and problems; it concludes with expansions, approximation methods, and convergence proofs. The German contribution is not overemphasized. The best coverage is for the period 1820 to 1900.

3648. Gårding, Lars. "The Dirichlet Problem". *The Mathematical Intelligencer* 2, No. 1 (1979), 43–53.

An expanded version of a talk for a student audience at Lund which covers the period from Poisson to Frostman in modern terminology.

3649. Vallée-Poussin, Charles-Jean-Gustave-Nicolas de la. "Gauss et la théorie du potentiel". *Revue des questions scientifiques* 133 (1962), 314–330.

This seminar was delivered in Brussels on 18 November 1939. It displays all the author's virtues: it is clear, honest, and balanced. The paper analyzes Gauss's 1840 paper in the *Resultate*, praising its virtues, stating its several defects and errors, pointing to their correction, and finally it gives a detailed picture of some of the priorities of authorship of principles, problems, and errors in potential theory and boundary value problems for elliptic differential equations.

3650. Monna, Antonie Frans. *Dirichlet's Principle: A Mathematical Comedy of Errors and Its Influence on the Development of Analysis.* Utrecth: Oosthoek, Scheltema en Holkema, 1975, vii + 138 pp.

An uneven history of the Dirichlet principle as applied to potential theory and complex function theory. It relies on German sources for the evaluation of Gauss and Green; it is unsatisfactory in its treatment of the French school from Chasles to Poincaré. But is gives an outline, from an expert, of the principle's purpose, development, and importance. An informal type of history, with 123 references, covering 1800–1940.

3651. Todhunter, Isaac. *A History of the Mathematical Theories of Attraction and the Figure of the Earth, from the Time of Newton to that of Laplace.* London: Macmillan and Co., 1873, xxxvi + 476 + 508 pp. 2 vols. Reprinted in 1 vol. New York: Dover, 1962.

This chronological list of contributions to the theory of gravitational attraction is very valuable. There are approximately 500 references; all these are analyzed, but no synthesis is attempted. Lagrange, Legendre, and Laplace are featured, and many prominent personages have at least one chapter devoted to their work. The related problem of the shape of the earth is covered from both the theoretical and practical points of view. The best coverage is for the period 1780 to 1820, but the work starts with Newton about 1680 and runs to the peak of Giovanni Plana's career around 1840.

PROBABILITY AND STATISTICS

General Works

3652. Biermann, K.-R. "Aus der Geschichte der Wahrscheinlichkeitsrechnung". *Wissenschaftliche Annalen* 5 (1956), 542–548.

A sketch of early developments in probability stemming from considerations of games of chance. Discusses Cardano, Pacioli, Tartaglia, Jacob Bernoulli, and Laplace.

3653. *Biometrika*. (Studies in the History of Probability and Statistics.)

An ongoing series of articles appearing regularly since 1955. The first 31 articles are reprinted in the two volumes of items 3661 and 3657. Subsequent contributions to the series can be found in issues of *Biometrika* published since 1973.

3654. Czuber, E. "Die Entwicklung der Wahrscheinlichkeitstheorie und Ihrer Anwendungen". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 7 (1898), 1–279.

A dated but thorough examination of several aspects of this multifaceted subject. Discusses foundations and early phases, application to theory of repeated trials, Bayes's Theorem, applications to legal and ethical philosophy, to statistics, and to error theory.

3655. Freudenthal, H., and H. G. Steiner. "Aus der Geschichte der Wahrscheinlichkeitstheorie und der mathematischen Statistik". *Grundzüge der Mathematik, IV.* Edited by H. Behnke, G. Bertram, R. Sauer. Göttingen: Vandenhoeck & Ruprecht, 1966, 149–195.

A sketch of the development of probability and statistics from mid-17th century to the present indicating connections with other intellectual disciplines and social problems. Although the strictly mathematical developments dominate the discussion, attention is also given to game theory, economic and social theory, approximation theory, and philosophical foundations.

3656. Haberman, Steven, and Trevor A. Sibbett. Eds. *History of Actuarial Science.* London: W. Pickering & Chatto, 1995. 10 vols.

Topics: life tables and survival model; life insurance mathematics; pensions; investment risk theory non-life insurance; multiple decrement and multiple state models; health and sickness insurance; experience studies and estimation of rates graduation of decremental rates. Includes bibliographical references and index.

3657. Kendall, M. G., and R. L. Plackett, eds. *Studies in the History of Statistics and Probability. Vol. 2.* New York: Macmillan, 1977.

This book and the companion volume, item 3661, bring together a valuable collection of essays, the large majority of which appeared in the

Biometrika series "Studies in the History of Probability and Statistics"; see item 3653.

3658. Krüger, Lorenz, Loraine J. Daston, and Michael Heidelberger, eds. *The Probabilistic Revolution.* Vol. 1. Lorenz Krüger, G. Gigerenzer, and M. S. Morgan, eds. *The Probabilistic Revolution.* Vol. 2. Cambridge, Mass., and London: MIT Press, 1987, 449 + 459 pp.

3659. Maistrov, L. E. *Probability Theory. A Historical Sketch.* Translated and edited by S. Kotz. New York and London: Academic Press, 1974.

See item 2099.

3660. Owen, D. B., ed. *On the History of Statistics and Probability.* New York and Basel: Marcel Dekker, 1976.

Proceedings of a 1974 symposium. Includes J. Neyman on the emergence of statistics in the United States, B. Harshburger on statistics in America from 1920 to 1944, W. G. Cochran on the early development of techniques in comparative experimentation, plus 18 other articles.

3661. Pearson, E. S., and M. G. Kendall, eds. *Studies in the History of Statistics and Probability. Vol. 1.* Darien, Conn.: Hafner, 1970.

This book and the companion volume, item 3657, bring together a valuable collection of essays, the large majority of which appeared in the *Biometrika* series "Studies in the History of Probability and Statistics"; see item 3653.

3662. Raymond, P. *De la combinatoire aux probabilités.* Paris: F. Maspero, 1975.

A lengthy discussion of the philosophical background, including the search for a "mathesis universalis," determinism versus free will, and early difficulties facing probability theory. There follow chapters on Pascal, Leibniz, and Jacob Bernoulli, as well as a short chapter on Huygens.

3663. Stigler, Stephen M. *The History of Statistics. The Measurement of Uncertainty before 1900.* Cambridge, Mass.: Harvard University Press, 1986. xviii + 410 pp.

Wide ranging essays reflecting deep research: librations of the moon (Tobias Mayer); the orbit of Saturn (L. Euler and P. S. Laplace); A. M. Legendre and the method of least squares; C. F. Gauss's claim in 1809 that he had made use of probabilty since 1795; weak law of large numbers (Jakob Bernoulli); the normal approximation to the binomial distribution (A. de Moivre); Laplace's statement in 1774 of the principle of inverse probability soon after the development of the concepts of error and estimation by T. Simpson, J. H. Lambert and J. L. Lagrange; social work (L. A. J. Quetelet), vital statistics (W. Lexis) and psychometrics (G. T. Fechner and W. Ebbinghaus); multivariate normality (F. Galton);

extensions of the multivariate normal theory (F. Y. Edgeworth, K. Pearson and G. U. Yule). See the review by H. O. Lancaster in **MR** 88a:01004.

3664. Todhunter, Isaac. *A History of the Mathematical Theory of Probability from the Time of Pascal to That of Laplace.* New York: Chelsea, 1949 reprint of the 1865 edition.

Covers such figures as Cardano, Kepler, Galileo, Pascal, Fermat, Huygens, Bernoulli (James and Daniel), Montmort, de Moivre, Euler, d'Alembert, Bayes, Lagrange, Condorcet, Trembley, with 150 pages devoted to Laplace. Separate sections for combinations, mortality, and life insurance.

3665. Westergaard, H. *Contributions to the History of Statistics.* London: P. S. King & Don, 1932.

See item 2101.

Pre-17th Century

3666. David, F. N. *Games, Gods and Gambling. The Origins and History of Probability and Statistical Ideas from the Earliest Times to the Newtonian Era.* London: Charles Griffin & Co., 1962.

Probably the best single account of the origins and early development of probability theory. Although the author relegates Cardano to a lesser position than does Ore (see item 3668), he receives a more sympathetic treatment than from Todhunter (see item 3664). Others considered are Galileo, Fermat, and Pascal, Huygens, Wallis, Newton, Pepys, and James Bernoulli. Also, the work of de Moivre receives strong recognition.

3667. Hacking, I. *The Emergence of Probability. A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference.* Cambridge: University Press, 1975.

See item 2098.

3668. Ore, Øystein. *Cardano: The Gambling Scholar.* Princeton: Princeton University Press, 1953.

Besides being an entertaining biography, Ore attempts to establish Cardano as the founder of modern probability theory. Contains a translation of his *Liber de Ludo Aleae* (†Book on Games of Chance†), plus a discussion of Cardano's contribution to the subject in the last chapter, "The Science of Gambling."

3669. Rabinovitch, Nachum L. *Probability and Statistical Inference in Ancient and Medieval Jewish Literature.* Toronto: University of Toronto Press, 1973, 205 pp.

Argues that probabilistic thinking has deep historical roots, and in particular held a central place in ancient and medieval rabbinical literature. The author illustrates the sophistication of Jewish conceptions by the diversity of ideas presented (relative frequency, equally likely events, probabilistic logic, and foundations of a probabilistic arithmetic). See also item 1628.

3670. Sheynin, O. B. "On the Prehistory of the Theory of Probability". *Archive for History of Exact Sciences* 12 (1974), 98–141.

Not confined to prehistory, but rather examines the extramathematical aspects of the theory: its role in jurisprudence, the fine arts, medicine, astronomy and astrology, and ancient and modern philosophy.

3671. Van Brakel, J. "Some Remarks on the Prehistory of the Concept of Statistical Probability". *Archive for History of Exact Sciences* 16 (1976), 119–136.

A philosophical essay motivated by the author's contention that recent studies (e.g., item 3670) have led to confusion by obscuring distinct notions of probability that have occurred historically. Distinguishes among the following concepts of probability: (1) epistemic notion of probable knowledge, (2) epistemic notion of chance, (3) empirical notion of permanence of statistical ratios, and (4) the conceptual notion of equipossible events.

17th Century to Present

3672. Barone, Jack, and Albert Novikoff. "A History of the Axiomatic Formulation of Probability from Borel to Kolmogorov: Part I". *Archive for History of Exact Sciences* 18 (1978), 123–190.

Argues that E. Borel's important paper of 1909 on "denumerable probabability"—containing his Zero-One Law, his Strong Law of Large Numbers, and his Continued Fraction Theorem—did not clearly grasp the relationship between probability and measure theory. Also discusses the polemic of 1912 between Borel and F. Bernstein, as well as the contribution of Hausdorff in 1914. See also Novikoff and J. Barone, "The Borel Law of Normal Numbers, the Borel Zero-One Law, and the Work of Van Vleck", *Historia Mathematica* 4 (1977), 43–65.

3673. Biermann, K.-R. "Ueber die Untersuchung einer speziellen Frage der Kombinatorik durch G. W. Leibniz". *Forschungen und Fortschritte* 28 (1954), 357–361.

Discusses Leibniz's technique for finding the number of combinations without repetition that contain a given element. Illustrated with tables.

3674. Box, J. F. *R. A. Fisher. The Life of a Scientist*. New York: Wiley, 1978.

A detailed biography written by Fisher's daughter and interlaced with a good deal of biology and statistics. Individual chapters are devoted to mathematical statistics, significance tests, design of experiments, scientific inference, and the biometrical movement. Evolution and eugenics are always in the foreground, but the mathematics is by no means slighted. See also item 3677.

3675. Dantzig, D. van. "Laplace probabiliste et statisticien et ses precurseurs". *Archives internationales d'histoire des sciences* 8 (1955), 27–37.

3676. Daston, Lorraine. *Classical Probability in the Enlightenment.* Princeton, New Jersey: Princeton University Press, 1988. xviii + 423 pp.

Argues that the concept of probabilistic expectation evolved in response to the need for rational decision making in society. Discusses economic, legalistic, psychological, and moral factors.

3677. Fienberg, S. E., and D. V. Hinkley. *R. A. Fisher: An Appreciation.* (Lecture Notes in Statistics, No. 1.) New York: Springer, 1980. x + 208 pp.

A series of 18 essays discussing various aspects of Fisher's researches in statistics. Among these aspects are the design of experiments, statistical estimation, conditional inference, and the analysis of variance. Includes a brief biography by J. Box, one of Fisher's daughters. See also her full-length biography, *R. A. Fisher: The Life of a Scientist* (New York: Wiley, 1978), item 3674.

3678. Garber, D., and S. Zabell. "On the Emergence of Probability". *Archive for History of Exact Sciences* 21 (1980), 33–54.

The authors attempt to refute Hacking's thesis (item 3667) that the emergence of probability theory in the 17th cnetury was due to the concomitant appearance of the modern notion of probability in the same era. They cite evidence that the concept of probability is much older, in works of Cicero, Quintilian, John of Salisbury, and Oresme. They also suggest that the link between probabilistic thinking and games of chance was not common until the early 17th century, and thus take the usual view that it was this connection that sparked the theory.

3679. Hacking, I. "Jacques Bernoulli's 'Art of Conjecturing'". *British Journal for the Philosophy of Science* 22 (1971), 209–249.

A philosophical inquiry into Bernoulli's *Ars conjectandi.* Hacking first examines the conceptual framework employed by Bernoulli; he then attempts to determine the statistical value of his limit theorem as a tool for inference.

3680. Hailperin, Theodore. "Probability Logic in the 20th Century". *History and Philosophy of Logic* 12 (1991), 71–110.

Part of a continuing study of the history of probability theory. The subject of probability logic was first identified as a discipline in the 1960's.

3681. Nagaoka, Kazuo. "A History of the Strong Law of Large Numbers". In Japanese. *Kagakusi Kenkyu* 28 (1989), 14–24.

The history of probability theory in the early twentieth century.

3682. Hald, Anders. *A History of Probability and Statistics and Their Applications Before 1750.* (Wiley Series in Probability and Mathematical Statistics: Probability and Mathematical Statistics.) New York: John Wiley & Sons, 1990. xvi + 586 pp.

Describes the contemporaneous development and interaction of three topics: probability theory and games of chance; statistics in astronomy and demography; and life insurance mathematics. See the review by H. O. Lancaster in **MR** 91c:01003.

3683. Ondar, H. O., ed. *About the Theory of Probability and Mathematical Statistics.* Moscow: Nauka, 1977. In Russian.

Correspondence of A. A. Markov and A. A. Tshuprov.

3684. Pearson, E. S. *Karl Pearson: An Appreciation of Some Aspects of His Life and Work.* Cambridge: University Press, 1938.

Contains excerpts of letters, a bibliography of his works, syllabi from lecture courses, including "The Geometry of Statistics and the Laws of Chance" (1891–1894), and "Theory of Statistics" (1894–1896). Only scant reference to his mathematics.

3685. Pearson, Karl. *The History of Statistics in the 17th and 18th Centuries Against the Changing Background of Intellectual, Scientific and Religious Thought.* Edited by E. S. Pearson. New York: Macmillan, 1978.

See item 2100.

3686. Plato, Jan von. *Creating Modern Probability. Its Mathematics, Physics, and Philosophy in Historical Perspective.* Cambridge/New York/Melbourne: Cambridge University Press, 1994, 323.

A history of the axiomatization of probability by A. N. Kolmogorov and its subsequent development.

3687. Schneider, Ivo. "Der Mathematiker Abraham de Moivre (1667–1754)". *Archive for History of Exact Sciences* 5 (1968–1969), 117–317.

Discusses the background to de Moivre's probabilistic studies leading to the 1718 publication *Doctrine of Chances.* Much of de Moivre's work had roots in probability theory, and he went beyond the classical application of probability to games of chance by addressing the problem of annuities and adopting Halley's conception of the "probability of life." He was the first to publish a mathematical law for decrements of life from a mortality table. See also item 2249.

3688. Shafer, G. "Non-Additive Probabilities in the Work of Bernoulli and Lambert". *Archive for History of Exact Sciences* 19 (1978), 309–370.

Discusses the pioneering work of Jacob Bernoulli and Lambert in this field.

3689. Sheynin, O. B. “Newton and the Classical Theory of Probability”. *Archive for History of Exact Sciences* 7 (1971), 217–243.

Newton’s views on probability theory are considered together with the probabilistic aspects of his work in chronology, error theory, design of experiments, and astronomy. The influence of his probabilistic ideas on de Moivre, Arbuthnot, Bentley, and Laplace is also discussed.

3690. Sheynin, O. B. “J. H. Lambert’s Work on Probability”. *Archive for History of Exact Sciences* 7 (1971), 244–256.

Discusses Lambert’s work on demographical statistics and error theory. Stresses the importance of his philosophical views, and his fundamental contribution of the principle of maximum likelihood.

3691. Sheynin, O. B. “D. Bernoulli’s Work on Probability”. *Rete. Struktrugeschichte der Naturwissenschaften* 1 (1972), 273–300.

The contents of eight memoirs published between 1738 and 1780 are examined. These deal with applications to demographic studies, political arithmetic and moral expectation, astronomy, and theory of errors. Bernoulli was the first to use differential equations in probability theory, and to introduce tests of statistical hypotheses. His influence on Laplace was comparable to that of de Moivre.

3692. Sheynin, O. B. “Finite Random Sums (A Historical Essay)”. *Archive for History of Exact Sciences* 9 (1973), 275–305.

Considers finite random sums in the 18th-century context of games of chance through the work of Lagrange to the early studies by Laplace. Illustrates the transition from a discrete to a continuous random variable in developments closely tied to practical problems of demography and error theory.

3693. Sheynin, O. B. “R. J. Boscovich’s Work on Probability”. *Archive for History of Exact Sciences* 9 (1973), 306–324.

Boscovich’s method of adjusting arc measurements is presented, as well as a manuscript which may be the first use of probability in the theory of errors. This manuscript deals with the stochastic behavior of the sum of several random variables, each with a particular discrete distribution. Another manuscript deals with the *lotto di Roma*.

3694. Sheynin, O. B. “P. S. Laplace’s Work on Probability”. *Archive for History of Exact Sciences* 16 (1976), 137–187.

A detailed analysis of Laplace’s *Théorie analytique des probabilités*, treating probability proper, limit theorems, and mathematical statistics. Discusses Laplace’s philosophy of probability and science, concluding that his determinism was in fact compatible with his probabilistic views. Also claims that the roots of Laplace’s work lay in natural science and not mathematics, and that this later proved to be an obstacle to the development of the theory, despite his numerous achievements.

3695. Sheynin, O. B. "Laplace's Theory of Errors". *Archive for History of Exact Sciences* 17 (1977), 1–61.

3696. Sheynin, O. B. "Poisson's Work in Probability". *Archive for History of Exact Sciences.* 18 (1978), 245–300.

Examines Poisson's concept of probability, randomness, and distribution, as well as his work on limit theorems, the law of large numbers, mathematical statistics, and applications to jurisprudence, plus a brief summary of the contents of his probability memoirs. Poisson introrudced random quantities and the cumulative distribution function, the generalized central limit theorem, and proved the law of large numbers for the case of Poisson trials.

3697. Sheynin, O. B. "Gauss and the Theory of Errors". *Archive for History of Exact Sciences* 20 (1979), 21–72.

3698. Stigler, S. "Napoleonic Statistics: The Work of Laplace". *Biometrika* 62 (1975), 503–517.

3699. Van der Waerden, Bartel Leendert. Historical precis to *Die Werke von Jakob Bernoulli. Vol. III.* Basel: Birkhäuser, 1975, 1–18.

3700. Yamazaki, E. "D'Alembert et Condorcet: quelques aspects de l'histoire du calcul des probabilités". *Japanese Studies in the History of Science* 10 (1971), 60–93.

A sympathetic reconsideration of d'Alembert's critique of the 18th-century theory of probability. Argues that Condorcet's views in the main supported d'Alembert's criticism.

Applications in Sociology and Biology

3701. Cullen, M. J. *The Statistica Movement in Early Victorian Britain. The Foundations of Empirical Social Research.* New York: Harvester Press/Barnes & Noble, 1975.

Covers the statistics gathered by governmental departments in Britain from 1832 to 1852. Also discusses the founding and activity of the Statistical Society of London, the Manchester Statistical Society, and other provincial societies.

3702. Pearson, Karl. *Life, Letters and Labours of F. Galton. Vol. 2.* Cambridge: University Press, 1924.

Chapter XIII discusses Galton's statistical investigations and their relationship to his anthropometric researches.

3703. Sheynin, O. B. "On the History of the Statistical Method in Biology". *Archive for History of Exact Sciences* 22 (1980), 323–371.

Concentrates on the use of the concept of randomness in evolutionary biology from Lamarck to Darwin.

3704. Walker, H. M. *Studies in the History of the Statistical Method with Special Reference to Certain Educational Problems*. Baltimore: Williams & Wilkins, 1929.

Follows the development of the normal curve, moments, percentiles, and correlation as they relate to educational statistics. The final chapter is on statistics as a subject of instruction in American universities.

Applications in Physics

3705. Brush, S. G. "Foundations of Statistical Mechanics". *Archive for History of Exact Sciences* 4 (1967), 145–183.

This paper is mostly physics, but the author also traces the mathematical background leading to the proof of the impossibility of ergodic systems by Plancherel and Rosenthal. An elementary digression on the work of Cantor, Borel, and Lebesgue helps to anchor the discussion, as does the reference to measure theory and the fundamental work of Brouwer and Baire.

3706. Brush, S. G. "A History of Random Processes I. Brownian Movement from Brown to Perrin". *Archive for History of Exact Sciences* 5 (1968), 1–36.

Follows the developments from Brown's experiments and their interpretation to the theories of Einstein, Smoluchowski, and Perrin. Physics predominates over mathematics in this article.

3707. Brush, S. G. "The Development of the Kinetic Theory of Gases VIII. Randomness and Irreversibility". *Archive for History of Exact Sciences* 12 (1974), 1–88.

A survey of cosmology, geology, the second law of thermodynamics, and entropy, statistics, and the kinetic theory as they came together in the 19th century. Other topics include Boltzmann's statistical theory of entropy, the recurrence paradox, and Planck's contribution to irreversible radiation processes.

3708. Schneider, Ivo. "Clausius' erste Anwendung der Wahrscheinlichkeitsrechnung im Rahmen der atmosphärischen Lichtstreuung". *Archive for History of Exact Sciences* 14 (1974), 143–158.

Seeks to establish that Clausius (in his work on meteorological optics) and not Maxwell was the first to apply probabilistic methods to physics.

3709. Schneider, Ivo. "Rudolf Clausius' Beitrag zur Einführung wahrscheinlichkeitstheoretischer Methoden in die Physik der Gase nach 1856". *Archive for History of Exact Sciences* 14 (1975), 237–261.

Traces the entrance of probability theory in the kinetic theory of gases. Starting with ideas of Laplace and Krönig, follows Clausius's use of probability theory and the mean free path to Maxwell's use of a molecular velocity distribution.

MATHEMATICAL QUANTUM THEORY

3710. Bell, J. S. *Speakable and Unspeakable in Quantum Mechanics–(Collected Papers on Quantum Philosophy).* Cambridge: Cambridge University Press, 1987. Second edition, 1993.

On the problems of hidden variables, the Einstein-Rosen-Podolski paradox, the measurement problem in quantum mechanics, etc.

3711. Bogoliubov, N. N., A. A. Logunov, and I. T. Todorov. *Introduction to Axiomatic Quantum Field Theory.* Translated by S. A. Fulling and L. G. Popova. Reading, Mass.: W. A. Benjamin, 1975.

This monograph on the mathematical foundations of quantum theory contains numerous important works in this area with valuable commentary and supplementary remarks.

3712. Bogoliubov, N. N., and D. V. Shirkov. *Introduction to the Theory of Quantized Fields, Third Edition.* Translation edited by S. Chomet. New York: Wiley-Interscience, 1980.

A comprehensive mathematical exposition of the quantum theory of fields, including the scattering matrix, renormalization group, and dispersion relations.

3713. Bratteli, O., and D. W. Robinson *Operator Algebras and Quantum Statistical Mechanics.* Vol. 1. New York: Springer-Verlag, 1979. Second edition, 1987.

The most important mathematical works related to applications in quantum theory are cited in the introduction.

3714. Coleman, S. *Aspects of Symmetry.* Cambridge: Cambridge University Press, 1985.

Selected lectures by Coleman on topics in quantum field theory, including unitary symmetry, broken scale invariance, renormalization of fields, spontaneous symmetry breakdown, etc.

3715. Cushing, J. T. *Quantum Mechanics–Historical Contingency and the Copenhagen Hegemony.* Chicago: University of Chicago Press, 1994.

Physical and mathematical discussion of the standard (Copenhagen) and the causal (de Broglie-Bohm) interpretations of quantum mechanics.

3716. Dyson, F. J. "Missed Opportunities". *Bulletin of the American Mathematical Society* 78 (1972), 635–652.

With the help of many historical references, Dyson indicates in this article the connections between mathematics and physics. In particular, the mathematical foundations of quantum theory are commented upon from an historical point of view.

3717. Glimm, J. "The Mathematics of Quantum Fields". *Advances in Mathematics* 16 (1975), 221–232.

This very general article provides an overview of works in quantum field theory, with explanation and commentary.

3718. Jammer, M. *The Conceptual Development of Quantum Mechanics*. New York: McGraw-Hill, 1966. Second edition Los Angeles, Calif.: Tomash Publishers; Woodbury, N.J.: American Institute of Physics, 1989. (History of Modern Physics, 1800–1950, 12.)

The chapter entitled "Rise of Matrix Mechanics" gives a short summary of the development of matrix theory and its connections with quantum mechanics. Another chapter, "The Statistical Transformation Theory in Hilbert Space," considers Hilbert's efforts to axiomatize quantum mechanics. Finally, von Neumann's contributions to the founding of mathematical quantum mechanics are described. Along with a short description of theoretical contributions, many citations to relevant literature are also provided.

3719. Jauch, J. M. "The Mathematical Structure of Elementary Quantum Mechanics". In *Symposium on the Development of the Physicist's Conception of Nature*. Edited by J. Mehra. Dordrecht: D. Reidel, 1973, (Symposium on the Development of the Physicist's Conception of Nature in the Twentieth Century, Miramare, Italy (Trieste), 1972.) 300–319.

Along with a description of quantum theory from a mathematical viewpoint, a series of historical comments and bibliographic references are also given. Above all, questions of the representation of permutations and scattering theory are considered and commented upon.

3720. Kuhn, T. *Black-Body Theory and the Quantum Discontinuity, 1894–1912*. New York: Oxford University Press, 1978. Reprinted Chicago: University of Chicago, 1987.

Part I deals with the classical phase of Planck's black-body theory from 1894 to 1906. Part II deals with the emergence of the quantum discontinuity between 1905 and 1912, and considers the work of Rayleigh, Jeans, Ehrenfest, Einstein, Lorentz, and W. Wien. An epilogue considers the decline of Planck's black-body theory, his "second theory" of radiation, its uses, and ultimate fate.

3721. Landau, L. D., and E. M. Lifshitz. *Quantum Mechanics–Nonrelativistic Theory*. Translated by J. B. Sykes, and J. S. Bell. London: Pergamon Press, 1958. Second edition, 1965.

A comprehensive and classic textbook.

3722. Mehra, J., and H. Rechenberg. *The Historical Development of Quantum Mechanics.* Vol. 1: *The Quantum Theory of Planck, Einstein, Bohr, and Sommerfeld*. Vol. II: *The Discovery of Quantum Mechanics, 1925.*

Vol. III: *The Formulation of Wave Mechanics and its Modifications, 1925-1926.* Vol. IV: *The Fundamental Equations and the Reception of the New Quantum Mechanics, 1925-1926.* Vol. V: *Erwin Schrödinger and the Rise of Wave Mechanics*. New York: Springer-Verlag, 1982-1987.

3723. Rechenberg, H. "Quanta and Quantum Mechanics". In *Twentieth Century Physics*. Edited by L. M. Brown, A. Pais, and B. Pippard. Bristol: IOP Publishing, 1995, 143-248.

This may be regarded as a summary account of the comprehensive history in Mehra–Rechenberg (3722), containing 206 references.

3724. Schweber, S. S. *QED and the Men Who Made It: Dyson, Feynman, Schwinger, and Tomonaa*. Princeton: Princeton University Press, 1994.

The most comprehensive and scholarly account of the development of the renormalization theory of quantum electrodynamics (QED), which is the prototype of the quantum field theories that constitute the current Standard Model of elementary particle interactions. The first two chapters give a brief outline of QED during the late 1920s and the 1930s.

3725. Schwinger, J., ed. *Selected Papers on Quantum Electrodynamics*. New York: Dover Publications, 1958.

Important papers in the development of QED, by Dirac, Fermi, Heisenberg, etc., as well as more recent authors, as selected by Schwinger.

3726. Van der Waerden, B. L., ed. *Sources of Quantum Mechanics*. Amsterdam: North-Holland, 1967.

A collection of the most important papers leading up to and including Heisenberg's matrix mechanics and Dirac's transformation theory, from 1917 to 1926, and an excellent 59 page introduction by the editor.

3727. Weinberg, Steven. *The Quantum Theory of Fields* Cambridge: Cambridge University Press, 1995. 2 vols.

Already a classic account of the subject, it includes an historical introduction.

3728. Wightman, A. S. "Hilbert's Sixth Problem: Mathematical Treatment of the Axioms of Physics". *Mathematical Developments Arising from Hilbert's Problems*. Providence, R.I.: American Mathematical Society, 1976, 147–240.

A comprehensive survey article on the axiomatization of physics, especially quantum mechanics and quantum field theory. Numerous works are cited and discussed.

3729. Wintner, A. *Spektraltheorie der unendlichen Matrizen. (Einführung in den analytischen Apparat der Quantenmechanik).* Leipzig: S. Hirzel, 1929.

A very mathematical monograph with many historical remarks and references to pertinent literature, which clarifies the status of the theory of Hilbert spaces before von Neumann. This work is itself an important primary source for mathematical quantum theory.

3730. Witt, B. S. de, and R. N. Graham. "Resource Letter IQM-1 on the Interpretation of Quantum Mechanics". *American Journal of Physics* 19 (1971), 724–738.

In addition to the most important works on quantum mechanics, a series of essential works on the mathematical foundations of quantum mechanics with remarks and commentary are to be found in Section V: "Logical Foundations."

MATHEMATICS AND RELATIVITY

General (Introductory Texts, Einstein, Collections)

3731. Abro, A. d'. *The Evolution of Scientific Thought from Newton to Einstein.* 2nd edition.New York: Dover, 1950.

An early, non-technical account, providing an introduction to the subject of relativity theory. Part I discusses the mathematics relevant to Einstein's theory (manifolds, non-Euclidean geometries, electromagnetic equations). Part II treats the fundamental ideas of special relativity, while Part III deals with the general theory.

3732. Debever, R. *Elie Cartan—Albert Einstein. Letters on Absolute Parallelism, 1929-1932.* Princeton: Princeton University Press, 1979.

Reproduces the lengthy correspondence between Einstein and E. Cartan. In 1922-23, Cartan had already classified the generalized Riemannian Spaces that admit an affine connection.

3733. Earman, J., M. Janssen, and J. D. Norton. *The Attraction of Gravitation: New Studies in the History of General Relativity.* Vol. 5. (Einstein Studies.) Boston: Birkhäuser, 1993.

A collection of papers based on talks given at the Third International Conference on the History and Philosophy of General Relativity, University of Pittsburgh, June 27-30, 1991. Individual articles are reviewed separately.

3734. Eisenstaedt, J., and A. J. Kox. *Studies in the History of General Relativity.* Vol. 3. (Einstein Studies.) Boston: Birkhäuser, 1992.

A collection of articles based on talks given in the Second International Conference on the History of General Relativity, Luminy, France, 1988. The articles in this collection are reviewed separately.

3735. Fölsing, A *Albert Einstein. Eine Biographie.* Suhrkamp, 1993. In German. English translation by E. E. Osers. *Albert Einstein. A Biography.* New York: Viking, 1997.

A comprehensive biography discussing both Einstein's scientific work and his social and political ideas and activities.

3736. Howard, D., and J. Stachel. *Einstein and The History of General Relativity.* Vol. 1. (Einstein Studies.) Boston: Birkhäuser, 1989.

The articles of this collection are reviewed separately.

3737. Jungnickel, C., and R. McCormmach. *Intellectual Mastery of Nature. Theoretical Physics from Ohm to Einstein.* Vol. 1: *The Torch of Mathematics 1800-1870.* University of Chicago Press, 1986.

A panoramic history of German theoretical physics, describing the social, institutional and intellectual elements that contributed to the emergence of the discipline. Focuses on the contributions of G. S. Ohm, Wilhelm Weber, Franz Neumann, and their contemporaries.

3738. Jungnickel, C., and R. McCormmach. *Intellectual Mastery of Nature. Theoretical Physics from Ohm to Einstein*. Vol. 2: *The Now Mighty Theoretical Physics*. University of Chicago Press, 1986.

A panoramic history of German theoretical physics, describing the social, institutional and intellectual elements that contributed to the emergence of the discipline. Focuses on the contributions of Planck, Einstein, Heisenberg, and their contemporaries.

3739. Lichnerowicz, A. "Géométrie et relativité". In *Development of Mathematics, 1900–1950*. Edited by Jean-Paul Pier. Basel: Birkhäuser, 1994, 431–441.

A concise discussion of the interaction between differential geometry and theoretical physics, with special attention to the ideas of Ricci, Levi-Civita, Elie Cartan, and the author.

3740. Pyenson, L. "Relativity in Late Wilhelmian Germany: the Appeal to a Pre-established Harmony Between Mathematics and Physics". *Arch. Hist. Ex. Sci.* 29 (1982), 137-157. Reprinted in *The Young Einstein - The Advent of Relativity*, pp. 137-157.

Analyzes how the pervasiveness of the idea of a pre-established harmony between mathematics and physics informed the intellectual atmosphere in Göttingen over the first two decades of the century, and, in particular, how it affected the reception of relativity among scientists working in that university.

3741. Pyenson, L. *The Young Einstein - The Advent of Relativity*. Bristol and Boston: Adam Hilger Ltd., 1985.

A collection of articles by the author, dealing with the early stages of Einstein's scientific career, and the factors that shaped it. The author suggests that this early phase was dominated by Einstein's natural tendency to follow his physical intuitions, and that, on the contrary, he later became involved with mathematical considerations as a main guide to his physical work. Several articles in the collection are reviewed separately.

3742. Reich, K. *Die Entwicklung des Tensorkalküls. Vom absoluten Differentialkalkül zur Relativitätstheorie*. Vol. 11. (Science Networks.) Basel: Birkhäuser, 1994.

A history of tensor calculus as the crucial mathematical tool for the formulation of General Relativity. Early examples of tensors without the tensor concept are identified in differential geometry (surface theory) and elasticity theory. But tensor calculus as it was used by Einstein and M. Grossmann is shown to have its roots in three different and largely independent fields. The development within the theory of differential invariants culminated in Ricci's absolute differential calculus. Within elasticity theory and crystallography the concept of a tensor was introduced by Voigt. A tensor concept also emerged in the development of vector calculus and its application to electrodynamics and special relativity. The tensor calculus employed by Einstein and Grossmann in the development and formulation of General Relativity provided a synthesis of these independent developments. It is argued that up to its use for the formulation of General Relativity Ricci's absolute differential calculus did not play any role in differential geometry and that a geometric interpretation of General Relativity was developed only after its formulation. Reviewed favorably by Struik, D. J. in *Historia Mathematica* 22 (1995), no. 3, 323–326, and less favorably by Detlef Laugwitz in **MR** 96j:01028.

3743. Roseveare, N. T. *Mercury's Perihelion from Le Verrier to Einstein.* Oxford: Clarendon Press, 1982.

A review of the attempts to explain the anomalous advance in the perihelion of mercury, starting with its discovery by Le Verrier. Discusses especially the works of Vulcan, Simon Newcomb, Seelinger, Le Sage, Clairaut, Ritz, Einstein, and Freundlich.

3744. Stachel, J. "History of Relativity". In *Twentieth Century Physics.* Vol. 2. Edited by L. Brown, A. Pais, and B. Pippard. Bristol, Philadelphia and New York: Institute of Physics Publishing and American Institute of Physics Press, 1995, 249-356.

A general account of the development of the theories of Special and General Relativity.

3745. Vizgin, V., and Ya. A. Smorodinskii. "Einstein: The Creation of the Theory of Relatvity and the Some Gnosiological Lessons". *Soviet Physics Uspekhi* 22 (7) (1979), 528-554. Originally in Russian; has been translated into English.

Discusses some characteristic methods of Einstein's approach to physics and compares it with Lorentz's and Poincaré's.

3746. Whittaker, Edmund Taylor *A History of the Theories of Aether and Electricity.* Vol. 2: *The Modern Theories, 1900–1926.* London: Thomas Nelson and Sons, 1953. Reprinted New York: Harper Torchbooks, 1960, 319 pp.

A classical account of the theories of aether and electricity. The author describes in this second volume "the revolution in physics which took place in the first quarter of the twentieth century", among which the theories of relavitity appear prominently, alongside quantum mechanics.

Special Relativity: Origins and Early Developments

3747. Corry, L. "David Hilbert and the Axiomatization of Physics (1894-1905)". *Arch. Hist. Ex. Sci.* 51 (1997), 89–197.

Analyzes Hilbert's early Göttingen lectures on axiomatization, and gives a detailed account of what Hilbert intended by his program for axiomatizing physical theories. This program had important repercussions on Hilbert's later incursion into General Relativity, and some years before that, also on the contributions of his colleague Minkowski to the mathematical elaboration of the special theory of relativity.

3748. Corry, L. "Hermann Minkowski and the Postulate of Relativity". *Arch. Hist. Ex. Sci.* 51 (4) (1997), 273-314.

Describes Minkowski's work on electrodynamics during the last years of his life, against the program for axiomatization of physics originally devised by his Göttingen friend and colleague David Hilbert. The author claims that the generally accepted view of Minkowski's work on electrodynamics, as an attempt to develop the "electromagnetic world view" is misleading.

3749. Galison, P. L. "Minkowski's Space-Time: From Visual Thinking to the Absolute World". *Hist. Stu. Phys. Sci.* 10 (1979), 85-121.

Discusses the centrality of Minkowski's geometrical background for the development of his idea of space-time, and how the latter dominated his new conception of physical reality.

3750. Goldberg, S. "Henri Poincaré and Einstein's Theory of Relativity". *American Journal of Physics* 35 (1967), 933–944.

Argues that Poincaré not only did not anticipate Einstein in developing the Special Theory of Relativity, but that in fact Poincaré was interested in developing an electron theory of matter and radiation, rather than a theory of relativity.

3751. Holton, G. "On the Origins of the Special Theory of Relativity". *American Journal of Physics* 28 (7) (1960), 627–636.

Analyses the origins of the Special Theory of Relativity, while emphasizing the continuity between this and other works of Einstein, and between Einstein and the classic, Newtonian tradition.

3752. Pyenson, L. "Hermann Minkowski and Einstein's Special Theory of Relativity". *Arch. Hist. Ex. Sci.* 17 (1977), 71–95. Reprinted in *The Young Einstein - The Advent of Relativity*, pp. 80-10.

Examines Minkowski's interpretation of Einstein's principle of relativity, emphasizing Minkowski's views on the relations between mathematics and physics. The author suggests that the different approaches of Minkowski and Einstein to the role of mathematics in physics explain the special fashion in which Minkowski received and interpreted Einstein's Special Theory of Relativity.

3753. Pyenson, L. “Physics in the Shadows of Mathematics: the Göttingen Electron-theory Seminar of 1905”. *Arch. Hist. Ex. Sci.* 21 (1979), 55-89. Reprinted in *The Young Einstein - The Advent of Relativity*, pp. 101-136.

Discusses a seminar taught in Göttingen in 1905 on electron theory, and shows how a group of very gifted mathematicians and phsyicists could develop the issue in its deepest details without thereby being led to the relativistic direction announced independently by Poincaré and Einstein in their articles published shortly thereafter.

General Relativity: Origins and Early Development

3754. Biezunski, M. “Inside the Coconut: The Einstein–Cartan Discussion on Distant Parallelism”. In *Einstein and The History of General Relativity.* Vol. 1. Edited by D. Howard, and J. Stachel. (Einstein Studies.) Boston: Birkhäuser, 1989, 315-324.

Describes the interchange of ideas between Einstein and Elie Cartan concerning distant parallelism. The author argues that this exchange represents one of the many attempts made by Einstein to unify gravitation and electromagnetism.

3755. Corry, L., J. Renn, and J. Stachel. “A Belated Decision in the Hilbert-Einstein Priority Dispute”. *Science* 278 Nov. 14 (1997), 1270–1273.

Examines previously unpublished evidence, that shows clearly that Hilbert did not formulate the generally-covariant equations of General Relativity before Einstein, and that sheds new light on Hilbert’s approach to the whole issue.

3756. Earman, J., and C. Glymour. “Einstein and Hilbert: Two Months in The History of General Relativity”. *Arch. Hist. Ex. Sci.* 19 (1978), 291-308.

The authors examine the evidence that Einstein’s field equations were in part due to Hilbert. After presenting the relevant correspondence, they conclude that Hilbert probably had communicated his own equations to Einstein a week prior to the latter’s accouncement of his own. They doubt, however, that Hilbert’s equations influenced Einstein, unless perhaps formally, although Hilbert may have hastened Einstein’s discontent with the earlier Einstein– Grossmann theory.

3757. Eisenstaedt, J. “The Early Interpretation of the Schwarzschild Solution”. In *Einstein and The History of General Relativity.* Vol. 1. Edited by D. Howard, and J. Stachel. (Einstein Studies.) Boston: Birkhäuser, 1989, 213-233.

Focuses mainly on the works of De Donder, Hadamard, Droste, Weyl, Flamm, De Sitter, Eddington, and De Jans.

3758. Goodstein, J. R. "The Italian Mathematicians of Relativity". *Centaurus* 26 (1983), 241-261.

Analyzes the involvement of Italian mathematicians in the development of the theory of relativity. It focuses on the crucial role of Max Abraham and Tullio Levi-Civita.

3759. Lanczos, C. "Einstein's Path from Special to General Relativity". In *General Relativity: Papers in Honour of J. L. Synge.* Edited by L. O'Raifertaigh. Oxford: Clarendon Press, 1972, 5-19.

A general overview of the development of ideas leading from Einstein's Special Theory of Relativity to his General Theory of Relativity.

3760. Reich, K. "Levi-Civitasche Parallelverschiebung, affiner Zusammenhang, Uebertragungsprinzip: 1916/17-1922/23". *Arch. Hist. Ex. Sci.* 44 (1992), 77-105.

Discusses the evolution of Levi-Civita's concept of parallel displacement, and its elaboration in the works of Hessenberg, Schouten, Weyl, and others.

3761. Reich, K. "The American Contributions to the Theory of Differential Invariants, 1900-1916". In *The Attraction of Gravitation: New Studies in the History of General Relativity.* Vol. 5. Edited by J. Earman, M. Janssen, and J. D. Norton. (Einstein Studies.) Boston: Birkhäuser, 1993, 225-248.

Describes the contributions to differential invariants by mathematicians working in the USA between 1900 and 1916: Charles N. Haskins, Heinrich Maschke, Joseph E. Wright, Edward Kasner, James B. Shaw, Edwin B. Wilson, and others.

3762. Renn, J., and T. Sauer. "Einsteins Züricher Notizbuch". *Phys. Blätter* 52 (1996), 865-872.

Analyzes in detail the contents of Einstein's manuscript booknote, dating from his Zürich years. This analysis helps reconstructing the complex evolution of ideas leading to the formulation of the field equations of General Relativity in 1915, and sheds new light upon the interaction of the physical, mathematical and heuristic elements behind Einstein's motivations.

3763. Scholz, E. "Hermann Weyl's Contribution to Geometry, 1917-1923". In *The Intersection of History and Mathematics.* Vol. 15. Edited by Ch. Sasaski, M. Sugiura, and J. W. Dauben. (Science Networks.) Basel: Birkhäuser, 1994.

Describes the central traits of Weyl's geometric thought during the time of his deepest involvement in General Relativity, and analyzes the interaction between these two aspects of his work.

3764. Stachel, J. "The Cauchy Problem in General Relativity - The Early Years". In *Studies in the History of General Relativity*. Vol. 3. Edited by J. Eisenstaedt, and A. J. Kox. (Einstein Studies.) Boston: Birkhäuser, 1992, 407-418.

The history of the Cauchy problem, or initial-value problem in General Relativity, is usually told as starting in 1939 with the work of Lichnerowicz. This article discusses earlier attempts to deal with the problem, in the works of Hilbert, George Darmois, and Karl Stellmacher.

3765. Vizgin, V. "Einstein, Hilbert, and Weyl: The Genesis of the Geometrical Unified Field Theory Program". In *Einstein and The History of General Relativity*. Vol. 1. Edited by D. Howard, and J. Stachel. (Einstein Studies.) Boston: Birkhäuser, 1989, 300-314.

Discusses Weyl's 1918 attempt at an unified field theory, and the various factors that conditioned its emergence: the Göttingen tradition, Weyl's contacts with Einstein, and his philosophical interests.

3766. Vizgin, V., and Ya. A. Smorodinskii. "From The Equivalence Principle to the Equations of Gravitation". *Soviet Physics Uspekhi* 22 (7) (1979), 489-513.

Describes the main stages in the discovery of the equation of the General Theory of Relativity by Einstein, including the role played by Hilbert in this discovery.

General Relativity: Later Developments (Unified Field Theories, Cosmology, Quantum Gravity)

3767. Berg, G. "On the Origin of the Concept of an Einstein Space". *Studies in the History of General Relativity*. Vol. 3. Edited by J. Eisenstaedt, and A. J. Kox (Einstein Studies.) Boston: Birkhäuser, 1992, 336-343.

Discusses the emergence of the concept of an Einstein space, in order to show the influence of the General Theory of Relativity on the subsequent development of differential geometry.

3768. Eisenstaedt, J. "Histoire et singularités de la solution de Schwarzschild (1915-1923)". *Arch. Hist. Ex. Sci.* 29 (1982), 157-198.

Discusses Schwarzschild's solution to the field equations of General Relativity, and later investigations on the problem of its singularities. The author describes the contributions of Droste, Eddington, Weyl, Hilbert, Lanczos, Painlevé, Gullstrand, Hadamard, and others.

3769. Vilain, C. "Spherical Coordinates in General Relativity from 1915 to 1960: A Physical Interpretation". In *Studies in the History of General*

Relativity. Vol. 3. Edited by J. Eisenstaedt, and A. J. Kox. (Einstein Studies.) Boston: Birkhäuser. 1992, 419–434.

Discusses the physical interest of certain coordinate systems used before 1960 in General Relativity. Focuses on the works of Eddington, Robertson and Synge.

3770. Vizgin, V. *Unified Field Theories in the First Third of the 20th Century.* Vol. 13. (Science Networks.) Boston: Birkhäuser, 1994. Translated from the Russian original (1985) by Julian Barbour.

A detailed account of the attempts to formulate unified field theories over the first three decades of the century. Especial attention is conceded to the works of Hilbert, Weyl and Einstein.

The Reception of Relativity

3771. Hentschel, K. *Interpretationen und Fehlinterpretationen der speziellen und der allgemeinen Relativitätstheorie durch Zeitgenossen Albert Einsteins.* Vol. 6. (Science Networks.) Basel: Birkhäuser, 1990.

A comparative study of various philosophical reactions to and interpretations of both the special and general theories of relativity. Includes a most extensive and comprehensive bibliography of some 3000 references.

3772. Warwick, A. "Cambridge Mathematics and Cavendish Physics: Cunningham, Campbell, and Einstein's Relativity, 1905-1914. Part I: the Uses of Theory". *Stu. Hist. Phil. Sci.* 23 (1992), 625-656.

A two part essay discussing the role of early commentaries on Einstein's work in Cambridge University. This first part focuses on the work of Ebenezer Cunningham, and argues that his work represented a direct contribution to Cambridge electrodynamics rather than a contribution to the development of relativity theory.

Experimental Aspects of Relativity

3773. Hentschel, K. "Einstein's Attitude Towards Experiments: Testing Relativity Theory 1907–1927". *Stu. Hist. Phil. Sci.* 23 (4) (1992), 593-624.

Challenges an accepted view of Einstein as a theorist who anticipated all essential experimental results. Argues that Einstein was extremely curious about certain experimental results, especially when empirically testable effects were closely linked to his newly proposed fundamental principles, which still lacked empirical support.

THERMODYNAMICS AND STATISTICAL MECHANICS

3774. Bellone, Enrico. *Aspetti dell'approccio statistico alla meccanica: 1849-1905.* Florence: G. Barbera Editore, 1972.

Surveys the theories of Laplace, Fourier, Carnot, Joule Waterstone, Rankine, Clausius, Maxwell, Boltzmann, and Planck.

3775. Bierhhalter, Guenter. "Das Hamiltonsche Prinzip und J. J. Thomsons Versuch einer mechanischen Grundlegung der Thermodynamik". *Centaurus* (1993), 36 102-116.

Discusses J. J. Thomson's attempt to reduce theory of heat to one fundamental law by the use of Hamilton Principle. This kind of approach was also done by Boltzmann, Clausius, and C. Szily.

3776. Brush, Stephen G. *The Kind of Motion We Call Heat: A History of the Kinetic Theory of Gases in the 19th Century.* Amsterdam and New York: North-Holland Publishing Company, 1976. Reprinted 1986.

Includes a chapter "Foundations of Statistical Mechanics 1845–1915" (previously published in *Archive for History of Exact Sciences* 4 [1968], 145-183) which discusses the "ergodic hypothesis" and its relation to developments in pure mathematics (G. Cantor's set theory, invariance of dimensionality). There is a complete bibliography of original works on kinetic theory and statistical mechanics, 1801–1900.

3777. Brush, Stephen G. "Proof of the Impossibility of Ergodic Systems: The 1913 Papers of Rosenthal and Plancherel". *Transport Theory and Statistical Physics* 1 (1971), 287-311.

Translations of the papers by A. Rosenthal (*Annalen der Physik* 42 [1913], 796-806), and M. Plancherel (*Annalen der Physik* 43 [1913], 1061-1063) that proved that the original Maxwell–Boltzmann hypothesis (that the point representing the configuration of a mechanical system goes through every point in the phase space) is mathematically impossible, using the results of L. E. J. Brouwer, R. Baire, and H. Lebesgue. The introduction discusses the historical background of this important application of "pure" mathematics to theoretical physics.

3778. Bryan, G. H. "Allgemeine Grundlegung der Thermodynamik". In *Encyklopädie der mathematischen Wissenschaften.* Vol. 5. 1903, Part B, 71-160.

Informative history of thermodynamics, where the role of Gustav Zeuner is emphasized in the development of the second law, as in Ernst Mach, *Principles of the Theory of Heat*, (Dordrecht: Reidel, 1986 translated from the 2nd German ed. of 1900]). See also article "Technische Thermodynamik", 232-319.

3779. Cardwell, D. S. L. *From Watt to Clausius: The Rise of Thermodynamics in the Early Industrial Age.* Ithaca, N.Y.: Cornell University Press, 1971.

Development of theories of heat stressing their relations to technology.

3780. Carnot, Sadi. *Reflexions on the Motive Power of Fire.* Translated and edited by Robert Fox from 1824 ed. Manchester: Manchester University Press; New York: Lilian Barber Press, 1986.

The introduction with references gives a suggestive history of thermodynamics from Carnot to W. Thomson and Clausius, 1-57.

3781. Garber, E. W. "Clausius and Maxwell's Kinetic Theory of Gases". *Historical Studies in the Physical Sciences* 2 (1970), 299-319.

Discusses influences of Clausius and Boltzmann on Maxwell in gas theory.

3782. Gibbs, J. Willard "R. Clausius". *Proceedings of the American Academy of Arts and Science at Boston* 16 (1889), 458-65. Also in *Scientific Papers of J. W. Gibbs.* Vol. 2. London: Longmans, Green, and Company. 1906, 261-267. New edition, London: Dover. 1961.

Gibbs, one of the powerful followers of "entropy" by Clausius, comments on his mechanical theory of heat (including gas theory).

3783. Grattan-Guinness, Ivor. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* Vol. 2. London and New York: Routledge, 1994.

Includes two articles, "Thermodynamics" by Eri Yagi (1171-1182), and "Statistical Mechanics" by S. Brush, (1242-1251) that introduce these fields and provides original and secondary historical references. The *Encyclopedia* is mainly for mathematicians (including the historians, and educators) rather than physicists.

3784. Hills, Richard L. *Power from Steam: A History of the Stationary Steam Engine.* Cambridge and New York: Cambridge University Press, 1989.

Discusses the theory of heat from a technological viewpoint.

3785. Hutchison, Keith. "Der Ursprung der Entropiefunktion bei Rankine und Clausius". *Annals of Science* 30 (1973), 341-364.

Discusses contributions by W. Thomson, Rankine, and Clausius. Exactly characterizes the difference between the approaches of Rankine and Clausius.

3786. Kim, Y. S. "Clausius's Endeavour to Generalize the Second Law of Thermodynamics". *Archives Internationals d'Histoire des Sciences* 33 (1983), 256-73.

Reflects on some traditional North British evaluations of the second law, started by P. G. Tait, *Sketch of Thermodynamics*, (David Douglas, 1868; second ed. 1877) in the 19th century.

3787. Klein, Martin J. “Clausius on Gibbs”. *Historical Studies in the Physical Sciences* 1 (1969), 127-149.

Gives an interesting analysis and background to Gibbs's paper, item 3782.

3788. Klein, Martin J. “Some Historical Remarks on the Statistical Mechanics of J. W. Gibbs”. In *From Ancient Omens to Statistical Mechanics; Essays on the Exact Sciences, Presented to Asger Aaboe*. Copenhagen: University Library, 1987, 281-289.

Discusses Gibbs's manuscript at Yale that deals with his approach to “irreversibility”.

3789. Koenig, Frederick O. “On the History of Science and of the Second Law of Thermodynamics”. In *Men and Moments in the History of Science*. Edited by Herbert M. Evans. Seattle: University of Washington Press, 1959, 57-111, 211-216.

Discusses the various formulations of the second law by Carnot, Clapeyron, and Clausius.

3790. Lervig, P. “What is Heat? C. Truesdell's View of Thermodynamics. A Critical Discussion”. *Centaurus* 26 (1982), 85-122.

Critiques from an historian's point of view rather than that of a modern physicist.

Reviews: Huilgol, R. R. *Mathematical Reviews* **MR** 85e:01024.

3791. Meheus, Joke. “Adaptive Logic in Scientific Discovery”. *Logique & Analyse* 143-144 (1993), 359-391.

Philosophical approach to Clausius's adaption of Carnot's caloric theory.

Reviews: *Mathematical Reviews* **MR** 97i:01019.

3792. Mendoza, E. “The Kinetic Theory of Matter, 1845-1855”. *Archives Internationals d'Histoire des Sciences* 32 (1982), 184-220.

Suggestive history for these years.

3793. Poincaré, Henri. *Thermodynamique*. Paris: Jacques Gabay, 1908. Second edition, 1995.

Textbook on thermodynamics, focusing on the historical development of Carnot and Clausius.

Reviews: Harman, Peter M., *Mathematical Reviews* **MR** 97d:01040.

3794. Smith, Crosbie W. "W. Thomson and the Creation of Thermodynamics: 1840-1855". *Archives for History of Exact Sciences* 16 (1977), 231-288.

A history of thermodynamics that makes use of manuscripts in the UK. In particular there are detailed studies of James Thomson, William's older brother, that make this paper interesting.

3795. Truesdell, Clifford A. "Early Kinetic Theories of Gases." *Archive for History of Exact Sciences* 15 (1975), 1-66.

Survey of theories of Euler, Herapath, Waterston, Clausius, Maxwell, and others, with a "critical bibliography of kinetic-statistical mechanics through 1866."

3796. Truesdell, Clifford A. *The Tragicomical History of Thermodynamics, 1822-1854.* New York: Springer-Verlag, 1980.

A critique of theories published in this period, from a mathematical standpoint. See also item 3293.

3797. Yagi, Eri. "Clausius's Mathematical Method and the Mechanical Theory of Heat". *Historical Studies in the Physical Sciences* 15 (1984), 177-195.

Points out that in Clausius's mechanical theory of heat, Carnot's theory is treated as a first order approximation while Clausius himself considered "heat expended" to the second order.

3798. van der Waals, J. D. *On the Continuity of the Gaseous and Liquid States.* Edited with an introductory essay by J. S. Rowlinson Amsterdam: North-Holland, 1988. First edition, 1873.

TOPOLOGY

3799. Adams, Rebecca. "The Beginnings of General Topology (1904-1914)". In *Proceedings of the Canadian Society for the History and Philosophy of Mathematics*. Edited by James J. Tattersall. Montréal: Université du Québec à Montréal, 1995, 90–96.

Discusses how G. Cantor's concept of limit point led to Fréchet's introduction of L-classes in 1904 (through the work of F. Riesz and the contributions of E. H. Moore's students), as well as to the definition of general topological spaces by Hausdorff in 1914.

3800. Arboleda, L. C. "Les recherches de M. Fréchet, P. Alexandrov, Sierpinski et K. Kuratowski sur la théorie des types de dimensions et les débuts de la topologie générale". *Archive for History of Exact Sciences* 24 (1981), no.4 339–388.

Using material from the Fréchet archive at the Paris Academy of Science the author studies how Fréchet formulated his notion of dimension (or "dimension type") to compare infinite-dimensional (abstract) topological spaces. Fréchet's correspondence also yields particular insights into the works of Sierpiński, Kuratowski, Alexandrov, Urysohn, Kerekjárto, Baire, Brouwer et al. during the years 1905 to 1930.

3801. Bollinger, Maja. "Geschichtliche Entwicklung des Homologie-begriffs". *Archive for History of Exact Sciences* 9 no. 2 (1972), 94–166.

A detailed history of homology from its beginnings to 1915 which gives a full account of Poincaré's contributions.

3802. Browder, William. "Commentary on topology". In *A Century of Mathematics in America*. Part II. The American Mathematical Society and The Mathematical Association of America, 1989, 347–351.

This commentary takes the year 1946 and the Princeton Bicentennial Conference discussion of topology as a landmark for, in the author's own terms, the "birth" of the field of compact transformation groups (in which classifying actions provide the main problems) and the "puberty" of algebraic topology (with the development of homotopy theory). The brief survey emphasizes how topology became a meeting ground for diverse areas of mathematics as well as for interaction with other fields.

3803. Ciesielski, Krzysztof, and Zdzisław Pogoda. "The Beginnings of Polish Topology". *The Mathematical Intelligencer* 18 no.3 (1996), 32–39.

This short article describes the efforts to establish a Polish school of point set topology, in the second decade of this century. It summarizes the contributions of that school.

3804. Dehn, Max, and Poul Heegaard. "Analysis situs". In *Encyklopädie der mathematischen Wissenschaften*. III.1.AB3. Leipzig: Teubner, 1907, 153-220.

A thorough survey of the topic up to 1907, written by contributors to the field. It includes a wealth of references.

3805. Dieudonné, Jean. *A History of Algebraic and Differential Topology. 1900–1960*. Boston: Birkhäuser, 1989.

A vast, detailed, and highly technical exposition of the problems and developments of algebraic and differential topology from Poincaré's first paper on "Analysis Situs" (1895) to the developments of cobordism and K-Theory in the 1960s. It includes the creation of simplicial techniques and homology, their first applications, and the development of homotopy in its relations to homology. The author uses modern terminology to present older ideas and focuses on the developments of algebraic techniques. The bibliography includes over 500 primary sources.A shorter, less technical version of this story appeared under the title "Une brève histoire de la topologie" in *Developments of Mathematics, 1900-1950*, edited by Jean-Paul Pier, (Basel, Boston, Berlin: Birkhäuser, 1994), 35-153. Unlike the book, this account includes the earlier contributions of Riemann as part of a "prehistory" of algebraic topology.

3806. Dubucs, Jacques-Paul "L. E. J. Brouwer: Topologie et Constructivisme". *Revue d'Histoire des Sciences et de leurs Applications*, 41 (1988), 133–155.

3807. Epple, Morritz. "Branch Points of Algebraic Functions and the Beginnings of Modern Knot Theory". *Historia Mathematica* 22 (4) (1995), 371–401.

The article analyses the work of Austrian mathematician Wilhelm Wirtiger on functions of several complex variables in an attempt to generalize Klein's approach to algebraic functions carried on during the years 1895-1905 and shows how this investigation led to the first computation of a knot group. Using the work of Dehn on knot theory as an example, the author demonstrates how eliminating the context of algebraic functions created the "shift" which shaped investigations on knots into an independent theory. The study draws on the Kuhnian concepts of "paradigm" and "normal science".

3808. Freudenthal, Hans. "Topologie in den Niederlanden: das erste Halbjahrhundert". *Nieuw Archief voor Wiskunde. Derde Serie* 26 no.1 (1978), 22–40.

The well-known twentieth-century topologist presents the little-known work of Gerritt Mannoury the first Dutch topologist in the twentieth century, who greatly influenced L. E. J. Brouwer the central figure of this account. The work of Brouwer is discussed on the basis of sources unpublished during Brouwer's lifetime. This article also surveys the works of E. R. van Kampen, J. C. H. Gerretsen, H. Freudenthal, W. Hurewicz, D. van Dantzig and J. de. Groot

3809. Hirsch, Guy. "Topologie". In *Abrégé d'histoire des mathématiques 1700-1900.* Edited by Jean Dieudonné. Vol. 2, Chap. X. Paris: Hermann, 1978, 211–266.

An overview of primarily twentieth-century developments in combinatorial and algebraic topology, this chapter now stands as an introduction to Dieudonné's more technical and comprehensive accounts.

3810. Johnson, Dale M. "Prelude to Dimension Theory: The Geometrical Investigations of Bolzano". *Archive for History of Exact Sciences* 17 (1977), 261–295.

Considers Bolzano's philosophical and mathematical motivation for considering the problem of dimension, and gives his two solutions (1817, 1840s).

3811. Johnson, Dale M. "The Problem of the Invariance of Dimension in the Growth of Modern Topology". *Archive for the History of Exact Sciences* Part I, 20 (1979), 97–188; Part II, 25 (1981), 85–267.

Johnson's thorough-going paper considers the views of Gauss and Riemann on geometry and manifolds as multiply extended manifolds, before treating G. Cantor and Dedekind's discussions in detail. Attempts to resolve Cantor's paradox (there is a one-to-one correspondence between the points of a square and an interval) by Lüroth, Thomae, Jürgens, and Netto are considered, and shown to lead (in the hands of Peano and Schoenflies) to the growth of point-set topology. Part II takes the invariance of dimension problem up to its solution by Brouwer, with emphasis given to the Brouwer-Lebesgue dispute. Documents and letters to Baire from Brouwer are included, along with "Glimpses of the Development of Dimension Theory after Brouwer." Errata to Part I are given in Part II, p. 267.

3812. Kline, Morris. "The Beginnings of Topology". Chapter 50 in *Mathematical Thought from Ancient to Modern Times.* New York: Oxford University Press, 1972, 1158-1181.

A very general introduction to the history of topology.

3813. Lefschetz, Solomon. "The Early Development of Algebraic Topology". *Boletim da Sociedade Brasileira de Matemática* 1 (1) (1970), 1–48.

Personal reminiscences of one of the founding members of an important twentieth-century discipline.

3814. Mac Lane, Saunders. "Origins of the Cohomology of Groups". *L'Enseignement Mathématique. Revue Internationale. IIe Série* 24 no. 1-2 (1978), 1–29.

This account traces the development cohomology theory as an algebraic study, starting with a discussion of the seminal paper by H. Hopf in 1941. The author then works backward in time to the 1920's and forward to the 1960's to deliver a vivid picture of algebraic topology and its influence on algebra, especially in the 1930's and 1940's with the contributions of Hopf, Hurewicz, H. Freudenthal, Eckmann, Baer, H. Cartan, Eilenberg, Mac Lane, et al. A contributor to the field, the author also comments on the professional contacts between these twentieth-century mathematicians.

3815. Moore, Gregory H. "The Warsaw School, Widening Applications, Models of Set Theory (1918-1940)". Chapter 4 in *Zermelo's Axiom of Choice. Its Origins, Development and Influence.* New York, Heidelberg, Berlin: Springer, 1982, 235–242.

Section 6 of this chapter offers a thorough but concise examination of the uses of some forms of the axiom of choice in the topological works of Hausdorff, Alexandroff, Urysohn, Tychonoff, Garrett Birkhoff, Henri Cartan, and Bourbaki. It focuses on the notions of convergence and compactness in general topology.

3816. Pier, Jean-Paul. "Historique de la notion de compacité". *Historia Mathematica* 7 no. 4 (1980), 425–443.

The author stresses the ties between the Bolzano-Weierstrass and Borel-Lebesgue properties of sets and the notion of compactness, and focusses on the contributions of Fréchet (1906), who gave the first formal definition of a compact set, and Hausdorff (1914).

3817. Pont, Jean-Claude. *La Topologie algébrique, des origines à Poincaré.* Paris: Presses Universitaires de France, 1974.

A careful account of the origins, with particular emphasis on the contributions of Euler, Gauss, Listing, and Moebius. The development of algebraic topology is less well served but is still informative. The homological ideas of Riemann (to do with integration), the emergence of the concept of manifold, and Poincaré's own work are scarcely discussed (some of these are discussed in Scholz, items 3062, 3089). Reviewed by Freudenthal, H., *Historia Mathematica* 3 (1976), 350–352.

3818. Scholz, Erhard. *Geschichte des Mannigfaltigkeitsbegriffs von Riemann bis Poincaré.* Boston, Basel, Stuttgart: Birkhäuser, 1980.

This careful study sees the concept of manifold through its different historical developments, revealing the geometric as well as the analytical background to this topological notion. It discusses at length the work of Riemann and of Poincaré.

3819. Tietze, Heinrich, and Leopold Vietoris. In "Beziehungen zwischen des verschiedenen Zweigen der Topologie". *Encyklopädie der* *mathematischen Wissenschaften*. III.1.AB13. Leipzig: Teubner, 1930, 141-237.

A survey of the developments of different branches of topology from 1907 to 1930 by contributors to the field.

3820. Van den Eynde, Ria. "Historical Evolution of the Concept of Homotopic Paths". *Archive for History of Exact Sciences* 45 no. 2 (1992), 127–188.

The article traces the evolution of homotopic paths, from their early intuitive uses in analysis (including the calculus of variations, analytic continuation, and differential equations) to their explicit formulation in topology.

3821. Weyl, Hermann. "Topology and Abstract Algebra as Two Roads of Mathematical Comprehension". *The American Mathematical Monthly* 102 (1995), Part I, 453–462; Part II, 646–651.

A translation by A. Shenitzer of a 1931 lecture by Weyl. Although not strictly historical the lecture brings insights into the interrelations of topology and algebra in the 1930s. Part I shows the connections between Riemann's topological study of algebraic functions and Weierstrass's algebraic investigations of analysis. Part II illustrates mathematical concept building by way of the notions of genus in topology and ideal in algebra.

3822. Wilder, Raymond L. "Evolution of the Topological Concept of 'Connected.'" *American Mathematical Monthly* 85 (1978), 720–726.

Analyzes nineteenth- and early twentieth-century researches on connectedness, especially those of B. Bolzano, G. Cantor, C. Jordan, W. H. Young, G. C. Young, N. Lennes, F. Riesz, and F. Hausdorff.

3823. Willard, Stephen. *General Topology*. London: Addison-Wesley, 1970.

Although not a history, this textbook includes 25 pages of historical notes on general topology, together with an excellent bibliography.

VI. THE HISTORY OF MATHEMATICS: SELECTED TOPICS

This final section is devoted to a number of ancillary topics, some of which have begun to receive increasing attention of late—especially the sociology of mathematics, the subject of women in mathematics, and ethnomathematics (though items on the latter have not been gathered into one category here).

MATHEMATICS EDUCATION

Mathematics education has two distinct aspects, considered as a special topic in relation to work on the history of mathematics. The history *of* mathematics education is a long-established topic of investigation within the history of mathematics, covered in part in the history of institutions. A rather different and rapidly growing area, which has developed considerably since the 1985 edition of this bibliography, is the exploration of relations *between* the history of mathematics and the practice of mathematics education. Such work is intended to bring resources developed within the historical community to the attention of mathematics teachers, in the context of various classroom needs and purposes. This latter category includes a wide range of rather different kinds of work, from theoretical discussions of relations within the curriculum to historical resource materials for teachers to use.

Some parameters of choices behind these entries may be noted. The material is for the most part confined to French- or English-language materials, with a bias towards mathematics education in the UK and US. A considerable amount of work in this area has been done in France in recent years, as will be clear from some of the entries, as well as in other European countries. However, this listing does not contain, to any great extent, works of straightforward historical exposition suitable for teachers and students. The books, journals and articles listed here are those containing some discussion *about* the use or incorporation of historical material in teaching and learning.

History of Mathematics Education

3824. Barrantes, Hugo and Angel Ruiz. *The History of the Inter-American Committee on Mathematics Education.* With an introduction by Ubiratan D'Ambrosio. (La historia des comite interamericano de educacion matematica). In Spanish. Coleccion Enrique Perez Arbelaez. 13. Bogota: Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, 1998.

3825. Bidwell, James K., and Robert G. Clason *Readings in the History of Mathematics Education*. Reston, Va.: National Council of Teachers of Mathematics. 1970.

Substantial excerpts from major documents spanning the period 1831-1959 in the US.

3826. Cajori, Florian. *The Teaching and History of Mathematics in the United States*. Washington, D.C.: Government Printing Office, 1890.

A history of mathematics education in the US up to the end of the 19th century, including a detailed report on the situation at the end of that period based on a large questionnaire survey. See item 4615.

3827. Hoskin, Keith. "Textbooks and the Mathematisation of American Reality: the Role of Charles Davies and the US Military Academy at West Point". *Paradigm* 13 (1994), 11-41.

The period 1830 to 1860 marks the emergence of American colleges and high schools as institutions providing differentiated curricula, in a classroom setting, following a regular progression over a number of years. These developments owe much to the work of Charles Davies at West Point.

3828. Howson, A. G. *A History of Mathematics Education in England*. Cambridge: Cambridge University Press, 1982.

Historical development over four centuries seen through contextualised studies of nine major educational figures: Robert Recorde Samuel Pepys, Philip Doddridge, Charles Hutton, Augustus De Morgan, Thomas Tate, James Wilson, Charles Godfrey, and Elizabeth Williams.

3829. Jackson, Lambert Lincoln. *The Educational Significance of Sixteenth Century Arithmetic: from the Point of View of the Present Time*. New York: Columbia University, 1906.

An exploration of arithmetic teaching in the early modern period, examined specifically for its bearing on teaching principles and practices in the 20th century.

3830. Jones, Phillip S., and Arthur Coxford, eds. *A History of Mathematics Education in the United States and Canada*. Reston, Va.: National Council of Teachers of Mathematics, 1970.

Emphasizes curricular and methodological changes in the elementary and secondary schools, and the issues and forces causing the changes. Extensive bibliography.

3831. Schubring, Gert. *Analysis of Historical Textbooks in Mathematics*. PUC do Rio de Janeiro, 1997.

A course of lectures on an important but little-explored subject, the history of mathematics textbooks.

3832. Siu Man-Keung. "Mathematics Education in Ancient China: What Lesson Do We Learn from It?" *Historia Scientiarum* 4 (1995), 223-232.

Most problems in classical Chinese mathematics were couched in a practical, applied, way, and that was generally taken as the justification of mathematics. This contrasts with Greek conceptions of mathematics, as seen for example in Plato, and may have contributed to a loss of esteem for the subject over time.

3833. Swetz, Frank. *Mathematics Education in China: its Growth and Development*. Cambridge, Mass.: MIT Press, 1974.

Discusses the position of mathematics in the traditional education system, the effects of the system on mathematical thinking and instruction, and the reforms from 1870 to 1970.

3834. Swetz, Frank. "To Know and to Teach: Mathematical Pedagogy from a Historical Context". *Educational Studies in Mathematics* 29 (1995), 73-88.

The contents of historical mathematical texts usually embody a pedagogy. Several pedagogical techniques are analysed: instructional discourse, logical sequencing of problems and exercises, employment of visual aids. Much of today's mathematical pedagogy derived from distant historical antecedents.

3835. Watson, Foster. *The Beginnings of the Teaching of Modern Subjects in England*. London: Pitman, 1909.

In its day a ground-breaking work, this book, which includes 150 pages on arithmetic, geometry and astronomy teaching, remains fascinatingly informative.

3836. Wilson, Duncan K. *The History of Mathematical Teaching in Scotland: to the End of the Eighteenth Century*. London: University of London Press, 1935.

The development of the teaching of arithmetic and elementary mathematics in Scotland up to the end of the eighteenth century: institutions, textbooks, and teachers.

3837. Yeldham, F. H. *The Teaching of Arithmetic Through Four Hundred Years*. London: Harrap, 1936.

Content, methods and style of popular arithmetic texts in England from the early sixteenth to the early twentieth centuries.

Relations Between History of Mathematics and Mathematics Education

Conceptual Discussions

This sub-section contains a range of materials and perspectives about using history in the mathematics classroom (including discussion of whether "using" is the right way to be thinking about it), together with some illustrative and representative case studies. Many more papers along these lines, but not separately noted here, are to be found within the books or journals listed in the next section.

3838. Bos, H. J. M. "Mathematics and its Social Context: A Dialogue in the Staff Room, with Historical Episodes". *For the Learning of Mathematics* 4 (3) (1984), 2-9.

The history of mathematics can inform both pupils and teachers about the social context of mathematics, and help them to decide what position they hold in debates about it.

3839. Branford, Benchara. *A Study of Mathematical Education*. Oxford: Clarendon Press, 1908, 420 pp.

A study of the thesis that the individual's mathematical development parallels that of human history, with its pedagogic implications.

3840. Dennis, David, and Jere Confrey. "Drawing Logarithmic Curves with Geometer's Sketchpad: A Method Inspired by Historical Sources". In *Geometry Turned On! Dynamic Software in Learning, Teaching and Research*. Edited by James R. King, and Doris Schattschneider. Washington, D.C.: Mathematical Association of America, 1997, 147-156.

A mechanical linkage device from Descartes's *Geometry*, for finding any number of points on a logarithmic or exponential curve, can be simulated on computer. Such a tool helps the dialogue between grounded activity and systematic inquiry, between physical investigations and symbolic language, in mathematics learning.

3841. Dorier, Jean-Luc. "On the Teaching of the Theory of Vector Spaces in the First Year of French Science Universities". *Edumath* 6 (1998), 38-48.

Historical analysis enables us to explain the specific meaning which formalism has in the theory, and thus the teaching, of vector spaces. Other pedagogical issues, including students' mistakes, can be understood and acted upon better through the study of history.

3842. Freudenthal, Hans. "Should a Mathematics Teacher Know Something about the History of Mathematics?" *For the Learning of Mathematics* 2 (1) (1981), 30-33.

The teacher's knowledge of history should be integrated knowledge, familiar to the teacher and a cornucopia available for instruction: not hidden in drawers to be opened at pre-established moments. For students and teachers, the history of mathematics should concern the processes rather than the products of mathematical creativity.

3843. Friedelmeyer, Jean-Pierre. "What History Has to Say to Us about the Teaching of Analysis". In *Teaching Mathematics: the Relationship*

Between Knowledge, Curriculum and Practice. Edited by Evelyne Barbin, and Régine Douady. Topiques éditions, 1996, 109-122.

Reforms in analysis teaching have attempted to reconcile the apparently irreconcilable needs for rigour and for understanding. Teaching in a historical context enables the meaning and rigour to be interactively constructed along with the students' mathematical insight, by a process which is dynamic and living.

3844. Furinghetti, Fulvia. "History of Mathematics, Mathematics Education, School Practice: Case Studies in Linking Different Domains". *For the Learning of Mathematics* 17 (is 1) (1997), 55-61.

Experiences of teachers exploring different ways of using history are discussed and taxonomised: informing students' image of mathematics, as a source of problems, as an optional activity, and as a different approach to concepts. "Integration" is preferable to "use" of history, to characterise a more methodical development and analysis.

3845. Furinghetti, Fulvia, and Annamaria Somaglia. "History of Mathematics in School Across Disciplines". *Mathematics in School* 27 (is 4) (1998), 48-51.

History of mathematics can help pupils see the genesis of ideas and connections between subjects, with real benefits for their seeing the homogeneity of knowledge as well as mathematical development. Several interdisciplinary projects relate mathematics and philosophy, art, music, etc. Students' mathematical difficulties are addressed by a considered approach drawing upon contexts from the history of mathematics.

3846. Grattan-Guinness, Ivor. "Not from Nowhere: History and Philosophy Behind Mathematical Education". *International Journal of Mathematical Education in Science and Technology* 4 (1973), 421-453.

Comparison of standard teaching method with the historical development of selected topics, arguing for "history satire": teaching based on close-to-original problems, to assist student understanding.

3847. Hefendehl-Hebeker, Lisa. "Negative Numbers: Obstacles in Their Evolution from Intuitive to Intellectual Constructs". *For the Learning of Mathematics* 11 (1) (1991) 26-32.

The intellectual hurdles that blocked the understanding of negative numbers thoughout history may also block the understanding of present-day students. The examples of D'Alembert and Stendhal illustrate the confusions. Among others, Hermann Hankel in 1867 sought to overcome the difficulties by a change of viewpoint.

3848. Katz, Victor J. "Using History in Teaching Mathematics". *For the Learning of Mathematics* 6 (3) (1986), 13-19.

Use of historical materials is profitable both for motivating students and for developing the curriculum, and can give rise to valuable pedagogic ideas. Examples are given from algorithms, combinatorics, logarithms, trigonometry, and mathematical modelling.

3849. Katz, Victor J. "Some Ideas on the Use of History in the Teaching of Mathematics". *For the Learning of Mathematics* 17 (1) 62-63.

To discover ways of making learning better for students, teachers need to experiment with various ways of using history and sharing the results. Successful use may require action on a larger scale: setting a series of ideas, or even a whole course, in historical context.

3850. Radford, Luis. "Before the Other Unknowns Were Invented: Didactic Inquiries on the Methods and Problems of Mediaeval Italian Algebra". *For the Learning of Mathematics* 15 (is 3) (1995), 28-38.

Didactical-epistemological analysis of problems and methods in Italian algebra from the 12th century onwards helps us understand the meaning of algebraic ideas, and helps draw out information that can be used in teaching: not to follow the same path, but to find new teaching possibilities (e.g. links between algebra and negative numbers).

3851. Radford, Luis. "On Psychology, Historical Epistemology, and the Teaching of Mathematics: Towards a Socio-cultural History of Mathematics". *For the Learning of Mathematics* 17 (1) (1997), 26-33.

The history of mathematics can be used, in a less naive way than anecdotally or as a source of problems, as an epistemological laboratory to explore the development of mathematical knowledge. This requires critical analysis of how historical and conceptual developments are linked-notably, of the notion of "epistemological obstacles"-through exploring how knowledge is rooted in its socio-cultural context.

3852. Radford, Luis. "The Roles of Geometry and Arithmetic in the Development of Algebra: Historical Remarks from a Didactic Perspective". In *Approaches to Algebra: Perspectives for Research and Teaching*. Edited by Nadine Bednarz, Carolyn Kieran, and Lesley Lee. Kluwer, 1996, 39-53.

The historical conceptual structure of our main modern elementary algebraic concepts, unknown and variable, are quite different. Exploring the history allows us to raise questions about the role geometry and arithmetic could play in teaching basic algebra concepts.

3853. Seltman, Muriel, and P. E. J. Seltman "Growth Processes and Formal Logic: Comments on History and Mathematics Regarded as Combined Educational Tools". *Int. J. Math. Educ. Sci. Technol.* (1978), 15-29.

History of mathematics, seen as permeating the whole of mathematics, can alleviate some of the teaching problems raised by the formal-logical character of mathematical thinking. Knowledge of the circumstances of mathematical discovery is integral to the access to, appreciation of and performance in mathematics.

3854. Siu Man-Keung. "The ABCD of Using History of Mathematics in the (Undergraduate) Classroom". *BHKMS* 1 (1997), 143-154.

Some teaching experience in using history of mathematics in the undergraduate classroom is shared through selected illustrative examples. These can be roughly categorized into four "levels" as (1) Anecdotes, (2) Broad outline, (3) Content and (4) Development of mathematical ideas.

3855. Speranza, Francesco, and Lucia Grugnetti. "History and Epistemology in Didactics of Mathematics". In *Italian Research in Mathematics Education 1988-1995.* Edited by Nicolina A. Malara, Marta Menghini, and Maria Reggiani. CNR, 1996, 126-135.

The interaction between mathematical didactics, and its history and epistemology, is rich, and in Italy is institutionalised. In the 1900s the relation was the subject of a rich debate; many writings from that period are still useful. The debate resumed in the 1980s, and now involves many groups across Italy.

Collections of Papers

The collections listed in this section are a representative selection of the works that have appeared with increased frequency in recent years, in which the experiences of several teachers and researchers are brought together, either in book form or as a special issue of an educational journal. In the present bibliography the individual papers in these collections are not, on the whole, listed separately, but may often be found on a more detailed listing such as the BSHM education abstracts on the WorldWideWeb (http://www.dcs.warwick.ac.uk/bshm/education.html)

Books

3856. Calinger, Ronald, ed. *Vita Mathematica: Historical Research and Integration with Teaching.* Washington: Mathematical Association of America, 1996, 359 pp.

Thirty papers on the integration of historical research with mathematics teaching: Aspray et al, Barbin, Bero, Calinger, Cooke, D'Ambrosio, Dadic, Fauvel, Flashman, Grabiner, Heiede, Hensel, Hitchcock, Hughes, J. Høyrup, Jahnke, Jozeau, Katz, Kidwell, Kleiner, Knorr, Kronfellner, Laubenbacher & Pengelley, Lumpkin, Michalowicz, Rickey, Rowe, Siu, Swetz, Tattersall.

3857. Fauvel, John, ed. *History in the Mathematics Classroom: the IREM Papers*. Leicester: The Mathematical Association, 1990. 141 pp.

Papers by French mathematics teachers associated with the IREM movement, the network of mathematics education research institutes throughout France which have promoted, through the Inter-IREM Commission on History of Mathematics and Epistemology, some of the best work on relations between history and pedagogy of mathematics. The nine studies in this volume are by Bühler, Friedelmeyer, Hallez, Horain, Jozeau, Lefort, Plane, Sip.

3858. Grattan-Guinness, Ivor, ed. *History in Mathematics Education*. (Cahiers d'histoire & de philosophie des sciences, 21). Paris: Belin, 1987, 208 pp.

Proceedings of a Symposium devoted to the uses of history of mathematics in teaching mathematics held in 1985 at the University of Toronto, sponsored by the International Commission on the History of Mathematics. Twelve papers, by seven authors, on the history of mathematical topics suitable for classroom use in schools and colleges, often with explicit discussion of educational questions: Arcavi, J. L. Berggren, Drake, Grattan-Guinness, Hughes, Pycior, Scriba.

3859. IREM de Besançon. *Contribution à une approche historique de l'enseignement des mathématiques*. Besançon, 1995, 486 pp.

Twenty-seven case-studies (in French) on introducing historical perspectives into mathematics teaching.

3860. Lalande, Françoise, François Jaboeuf, and Yvon Nouazé, eds. *Histoire et épistémologie dans l'education mathématique*. IREM de Montpellier, 1995. 598 pp.

Fifty-eight papers presented at the first European Summer University on history and epistemology in mathematics education, held at Montpellier in 1993.

3861. Nobre, Sergio, ed. *Proceedings of HPM Meeting, Blumenau, Brazil 1994*. 231 pp.

Twenty-three papers on relations between history and pedagogy of mathematics: nine papers are in English (Carvalho e Silva, Frankenstein, Figoli, Gerdes, C. V. Jones, Kleiner, Nobre, Saraiva, Voolich), the remainder in Portuguese.

3862. Swetz, Frank, John Fauvel, Otto Bekken, Bengt Johansson, and Victor Katz, eds. *Learn from the Masters!* Washington: Mathematical Association of America, 1995, 303 pp.

Twenty-three papers on the history of mathematics as a pedagogic tool in the teaching of mathematics, presented at a conference in Norway in 1988 (the title is a quotation from the great Norwegian mathematician Niels Henrik Abel). Authors are Aiton, Avital, Bekken, Burton and Van Osdol, Fauvel, Gardiner, Helfgott, P. S. Jones, Katz, Kleiner, Lehmann, van Maanen, Mejlbo, Reich, Rickey, Shenitzer, Siu, Swetz.

3863. Veloso, Eduardo, ed. *Historía e Educaç åo Matemática*. Braga/Lisbon, 1996, 328 pp., 475 pp. 2 vols.

Eighty-three presentations, and further materials, ranging from studies of the use of history in classrooms across the world to historical accounts suitable for teachers and students. Languages: English, French and Portuguese.

Journals

3864. *Educaç åo matemática* 27 (1993), special issue entitled *História e ensino da matemática*, edited by Vieira, Ana, Eduardo Veloso, and José Manuel Matos.

Nine papers on the relations between history and pedagogy of mathematics, in Portuguese: Barbin, Carvalho e Silva, Estrada, Fauvel, Lino, Matos, Morgado, Rino, Silva.

3865. *For the Learning of Mathematics* 11 no. 2 (1991), special issue on history in mathematics education, edited by Fauvel, John.

Fourteen papers on relations between history and pedagogy of mathematics: Arcavi, Barbin, Brown, Fauvel, Fowler, Führer, Gardner, van Maanen, Ofir, Perkins, Ransom, Rogers, Thomaidis, Zaslavsky. Together with a bibliographical index of the 36 articles in this area appearing in the journal hitherto.

3866. *Mathematical Gazette* 76 no.475 (1992), special edition on the use of the history of mathematics in the teaching of the subject, edited by MacKinnon, Nick.

Fifteen papers: Crilly, Führer, Furinghetti, Gardiner, Hadley and Singmaster, Heiede, Kool, van Maanen, MacKinnon, Ofir and Arcavi, Pritchard, Ransom, Smith.

3867. *Mathematics in School* 26 no. 3 (1997), special history issue, edited by Bradshaw, John and Lesley Jones.

Seven papers: Sawyer, Joseph, Oliver, French, Downes, Rothman, Taverner.

3868. *Mathematics in School* 27 no.4 (1998), extra special issue on history of mathematics, edited by Earle, John.

Fourteen papers: Barrow-Green, Burn, Eagle, Ernest, Fauvel, Furinghetti and Somaglia, van Maanen, Maher, Ponza, Rice, Robson, Van Brummelen,Weeks.

3869. *Mathematik lehren* 19 (December 1986), special issue entitled *Geschichte-Geschichten*, edited by Führer, Lutz.

Papers (in German) include Führer, Kretzschmar, Windmann.

3870. *Mathematik lehren* 47 (August 1991), special issue entitled *Historische Quellen für den Mathematikunterricht*, edited by Schoenbeck, Jürgen.

Papers (in German) include Jahnke, Rieche, Rieche and Maier, Zimmermann.

Classroom Resource Material

3871. Eagle, M. Ruth. *Exploring Mathematics Through History.* Cambridge: Cambridge University Press, 1995. 108 pp.

Over 50 photocopiable worksheets and resource sheets for classroom use.

3872. Fauvel, John. *Mathematics Through History: A Resource Guide*. York: QED Books, 1990. 46 pp.

Annotated bibliography of works useful for mathematics teachers wishing to explore the historical dimension in their teaching.

3873. Hallerberg, Arthur E., et al, eds. *Historical Topics for the Mathematics Classroom.* Reston, Va.: National Council of Teachers of Mathematics, 1969. 2nd edn, 1989. 542 pp.

A classic resource-book for the school and college teacher: the historical materials for mathematics instruction include essays as well as 120 "capsules" (short essays of several paragraphs) of information on various historical topics.

3874. Inter-IREM Commission. *History of Mathematics. Histories of Problems.* Paris: Ellipses, 1997, 429 pp.

Essays on the birth and development of fifteen "great problems", showing the creation of mathematical tools needed for their solution, providing rich materials and resources for teachers and their students. An English translation, by Chris Weeks of the original French edition *Histoires de problèmes Histoire des mathématiques* (Ellipses, 1993). Chapters by Barbin and Itard, Belet and Belet, Bessot and Le Goff, Bkouche and Delattre, Chabert, Chabert, Crubellier and Sip, Daumas and Guillemot, Delattre and Bkouche, Friedelmeyer and Volkert, Friedelmeyer, Grégoire, Guillemot and Daumas, Jaboeuf, Plane.

3875. Boyé, Anne, et al. *Images, imaginaires, imaginations: une perspective historique pour l'introduction des nombres complexes.* Paris: Ellipses, 1998, 400 pp.

Materials for the learning of complex numbers: two chapters on their history, five on teaching experiences and suggestions within this context, and two setting the materials in a philosophical framework. Many primary sources, a large bibliography, and biographical notes. Authors are from the inter-IREM movement: Boyé, Clero, Durand-Richard, Friedelmeyer, Hallez, Hamon, Kouteynikoff, Thirion, Verley. A good example of the high quality work being done in France on detailed practical aspects of teaching mathematics with a historical dimension.

3876. Smith, Sanderson. *Agnesi to Zeno: Over 100 Vignettes from the History of Mathematics.* Berkeley, California: Key Curriculum Press, 1996, 266.

Each vignette is a brief introduction to a mathematician, concept or theme from the history of mathematics, with suggested classroom activities to encourage critical thinking and further exploration.

3877. Swetz, Frank J. *Learning Activities from the History of Mathematics.* Portland, Maine: J. Weston Walch, 1994, 269 pp.

Problem-solving activities and learning tasks on photocopiable pages as a classroom resource for teachers.

Course Descriptions

3878. Arcavi, Abraham, Maxim Bruckheimer, and Ruth Ben-Zvi. "History of Mathematics for Teachers: the Case of Irrational Numbers". *For the Learning of Mathematics* 7 (2) (1987), 18-23.

The development and implementation of a course on irrational numbers, taught through worksheets with further materials and answer sheets. The course objectives were to strengthen the teachers' knowledge, pursue other pedagogic issues, develop work around primary sources, and foster an image of mathematics as creative human endeavour.

3879. Fowler, David H. "A Final-year University Course on the History of Mathematics: Actively Confronting the Past". *The Mathematical Gazette* 76 no 475 (1992), 46-48.

Regarding history as the active confrontation of the past and the present, students on this course were encouraged to (a) read a selection of texts, writing a short description and a short essay on their reactions; (b) give a 15-minute talk to the class at some stage; (c) write a substantial essay. Some of the skills this course develops are notoriously neglected in mathematics courses, and are in demand in the outside world.

3880. Kleiner, Israel. "Famous Problems in Mathematics: Outlines of a Course". *For The Learning of Mathematics* 6 (1) (1986), 31-38.

Description of a third-year course with a significant historical perspective, offered at York University, Toronto, Ontario, which attempts to make students more "mathematically civilized", to legitimize the value of talking about mathematics as well as doing it.

3881. Laubenbacher, Reinhard, and David Pengelley. "Great Problems of Mathematics: A Course Based on Original Sources". *American Mathematical Monthly* 99 (1992), 313-317.

This course aimed at giving students the "big picture", examining the evolution of selected great problems from five mathematical subjects. Crucial to achieving the goal was the use of original sources to demonstrate the fundamental ideas, allowing students to appreciate how clarity and sophistication of concepts and techniques develop through time.

HISTORY OF INSTITUTIONS

This is the first attempt to establish an international bibliography on the history of mathematical institutions. There might be considerable gaps in it; hints to titles left out will be welcome. Please note that institutional histories are also included in the sections of this bibliography devoted to specific countries or regions, e.g. the section on North America.

3882. Archibald, Raymond C. *A Semicentennial History of the American Mathematical Society 1888–1938.* New York: American Mathematical Society, 1938, xi + 262 pp.

Includes chapters on the history of the Society, its financial affairs, meetings, Gibbs Lectureship, library, Council and Board of Trustees, Chicago section, *Bulletin*, *Transactions*, and Colloquium Lectures and Publications. More than half of the volume is devoted to biographical and bibliographical notes on the Society's chief secretaries and past presidents.

3883. Aspray, William. "The emergence of Princeton as a World Center for Mathematical Research, 1896–1939". In *History and Philosophy of Modern Mathematics (Minneapolis, MN, 1985).* Minneapolis: University of Minnesota Press, 1988, 195–215.

The paper retraces the events which, beginning around 1900, transformed an average American university mainly devoted to undergraduate teaching into a center for mathematical research with world renown. It studies in particular the activity of three key persons promoting this process: H. Fine, O. Veblen, and S. Lefschetz. The paper is reprinted in *A Century of Mathematics in America*, Part II, 1989, 346–366. See review by J. Dieudonné in **MR** 89f:01087.

3884. Ausejo, Elena. *Por la Ciencia y por la Patria: La Institucionalizacion cientifica en España en el primer Tercio del Siglo XX.* Madrid: Siglo XXI de España Editores, 1993.

The book gives an in-depth analysis of the "Asociación Española para el Progresso de las Ciencias", the Society for the promotion of studies in the exact and descriptive sciences, founded in 1908 in the wake of the national renovation movement of 1898. It studies the evolution of the society, mainly by one of its main activities, its Congresses, and gives precise information about its members and its organization. Particularly valuable is the chapter which provides a comparative study of the evolution of homologous associations abroad, starting from the model, the British Association for the Advancement of Science. One chapter is devoted to an analysis of the mathematical contributions produced by the association's members.

3885. Ausejo, Elena, and Ana Millán. "The Spanish Mathematical Society and its Periodicals in the First Third of the 20th Century". In *Messengers of Mathematics: European Mathematical Jornals (1800-1946).* Edited by Elena Ausejo, and Mariano Hormigon. Madrid: Siglo XXI de Espanã Editores, 1993, 159-187.

The paper studies the activities of the Spanish Mathematical Society, founded in 1908, until the Civil War and the interventions by the Franco regime. In particular, the development of the journals published by the Society is analyzed: first, the *Revista de la Sociedad Matematica Espanõla* (1911-1917), and after 1919, the *Revista Matematica Hispano-Americana* (1919-1940).

3886. Baayen, P. C. "'Wiskundig Genootschap' 1778–1978: some facts and figures concerning two centuries of the Dutch Mathematical Society". *Nieuw Archief voor Wiskunde. Derde Serie* 26 no. 1 (1978), 177–205.

The development of the Dutch Mathematical Society is analyzed from its founding in 1778 when it was the second purely mathematical society in Europe, following that of Hamburg (1690). While their first century was rather uneventful, the second documents the decisive progress of Dutch mathematicians. See review by D. J. Struik in **MR** 81i:01016.

3887. Ball, Walter W. Rouse *A History of the Study of Mathematics at Cambridge*. Cambridge: Cambridge University Press, 1889, xvii + 264 pp.

Notes on eminent Cambridge mathematicians, in particular the Newtonian and Analytical schools, from the 14th century to about 1859. Valuable for its detail on the structure of Cambridge studies and on the very important role of mathematics in those studies, especially through the mathematical tripos. See also item 2297.

3888. Berkel, K. van. "Het onderwijs in de wiskunde in Franeker in vergelijkend perspectief". *It Baeken* (1985), 214-235.

Franeker, a small town in the Friesian province of the Netherlands, had been endowed since 1585 with a university of Calvinist orientation—until its dissolution in the French period. The author describes the life and work of the first mathematics professors and presents the success of the first professors. He discusses reasons for the decline which ensued after only a few decades.

3889. Biermann, Kurt-R. *Die Mathematik und ihre Dozenten an der Berliner Universität, 1810–1933. Stationen auf dem Wege eines mathematischen Zentrums von Weltgeltung*. 2nd edition Berlin: Akademie-Verlag, 1988, 391 pp.

Surveys the work of such Berlin mathematicians as Dirichlet, J. Steiner, C. G. J. Jacobi, Kummer, Weierstrass, Kronecker, and Frobenius. Includes much information on the German Academy of Sciences, lists of *dozenten*, dissertations, *habilitationen*, prize problems, samples of the curriculum, and many informative documents. This second edition is supplemented by a chapter on the era of

Schmidt-Schur-Bieberbach-von Mises, from 1920 to 1933. It constitutes the standard reference for mathematics at Berlin University. See the review by S. L. Segal in **MR** 89k:01037.

3890. Bockstaele, P. "Mathematics in the Netherlands from 1750 to 1830". *Janus* 65 (1978), 67-95.

In this paper, the successive professors of mathematics at the universities of the Northern Provinces (nowadays the Netherlands) and of the southern provinces (Belgium since 1830) and their major activities are presented. The changes during the period of French hegemony (1795 to 1814) and the subsequent reforms are depicted.

3891. Bottazzini, Umberto. "The Italian States". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1495-1504.

An overview of the development of mathematics and mathematical centers in Italy since the Renaissance, with special emphasis on the 19th century and the early 20th century.

3892. Brigaglia, Aldo, and Guido Masotto. *Il Circolo Matematico di Palermo.* Bari: Edizioni Dedalo, 1982, 443 pp.

Using the archive material of G. B. Guccia founder of the Circolo Matematico di Palermo, the authors draw a detailed picture of the association's history from its beginnings in 1884 until World War I and outline its development until recent times. The main importance of the Circolo is due to its journal, the *Rendiconti*, which—during some decades between the end of the nineteenth century and the early 20th century—was highly attractive for mathematicians all over Europe. See review by Umberto Bottazzini in **MR** 84d:01077.

3893. Burckhardt, Johann Jakob. *Die Mathematik an der Universität Zurich, 1916–1950.* Basel and Boston, Mass.: Birkhäuser Verlag, 1980, 48 pp.

In this booklet, the research and teaching which took place at Zurich between1916 to1950 is outlined, referring especially to the main mathematicians active in this period: R. Fueter, A. Speiser and P. Finsler. See review by Werner Jentsch in **MR** 82m:01075.

3894. Chemnitius, Fritz. *Die Mathematiker, Astronomen und Physiker an der Universität Jena [1558-1914]. Kommentierte Edition des Manuskripts von Fritz Chemnitius (1930).* Vol. 7. Edited by Gert Schubring. (Reihe Algorismus.) München: Institut für Geschichte der Naturwissenschaften, 1992, xxxii + 105 pp.

The book gives biographical information on all the teachers of mathematics, astronomy, and physics at Jena University from its foundation in 1558. The manuscript of this text, found in the Nachlass of

Wilhelm Lorey, is introduced and commented on by Gert Schubring and complemented by a bibliography.

3895. Christmann, Erwin. *Studien zur Geschichte der Mathematik und des mathematischen Unterrichts in Heidelberg. Von der Gründung der Universität bis zur combinatorischen Schule*. Dissertation. Universität Heidelberg, 1925, 159 pp.

This Ph.D. thesis describes in its first chapter the marginal status of mathematics at Heidelberg university (founded in 1386) during the late Middle Age. The second chapter deals with the first institutionalization of a nominal mathematics professorship in 1547, due to the Humanist movement. The third chapter analyses the decline during the eighteenth century, because of several wars and the take-over by the Jesuits. The fourth chapter is devoted to the reforms under the new government of the Great-Dukedom of Baden since 1804 and the subsequent development of the combinatorial school. The book presents biographical information on the mathematics professors and lecturers at Heidelberg University and detailed information on their teaching.

3896. Crosland, Maurice. *The Society of Arcueil. A View of French Science at the Time of Napoleon I.* London: Heinemann, 1967, xx + 514 pp.

Explores the organization and patronage of science in early nineteenth-century France. Laplace, Biot, Arago, and Poisson were among the members of the society. Its leaders, Laplace and Berthollet, promoted a research program which stressed the mathematization of the experimental sciences.

3897. Dhombres, Jean. "L'enseignement des mathematiques par la "méthode révolutionnaire". Les leçons de Laplace a l'École Normale de l'an III". *Revue d'Histoire des Sciences et de leurs Applications* 33 no. 4 (1980), 315–348.

An analysis of the mathematics teaching at the first École Normale, the short-lived Teachers College fom the revolutionary period when new educational institutions were being established, and of the mathematics lectures given by the leading French mathematicians of that time. See review by I. Grattan-Guinness in **MR** 83e:01087.

3898. Duren, Peter, et al., eds. *A Century of Mathematics in America—Part II.* Providence: American Mathematical Society, 1989, x + 585 pp.

This important collection contains numerous papers on the history of mathematical institutions in the United States of America. The following gives a list of the most pertinent papers. For more detailed information see the section on North America, beginning with item 4598.

Garrett Birkhoff, "Mathematics at Harvard, 1836–1944", 3–58; Harold L. Dorwart, "Mathematics and Yale in the Nineteen Twenties", 87–97; Saunders Mac Lane, "Mathematics at the University of Chicago:

A Brief History", 127–154; William Aspray, "The Emergence of Princeton as a World Center for Mathematical Research, 1896–1939", 195–215; Halsey Royden, "A History of Mathematics at Stanford", 237–277; Robin E. Rider, "An Opportune Time: Griffith C. Evans and Mathematics at Berkeley", 283–302; Cathleen S. Morawetz, "The Courant Institute of Mathematical Sciences", 303–307; Peter D. Lax, "The Flowering of Applied Mathematics in America", 455–466.

3899. Duren, Peter et al., eds. "A Century of Mathematics in America—Part III". Providence: American Mathematical Society, 1989, x + 675 pp.

See the commentary to Volume II, item 3898.The following is a list of the most pertinent papers: Karen Hunger Parshall and David E. Rowe, "American Mathematics Comes of Age: 1875–1900", 3–28; Roger Cooke and V. Frederick Rickey, "W. E. Story of Hopkins and Clark", 29–76; Armand Borel, "The School of Mathematics at the Institute for Advanced Study", 119–147; Edgar R. Lorch, "Mathematics at Columbia during adolescence", 149–161; Dirk J. Struik, "The MIT Department of Mathematics during its First Seventy-five Years: some recollections", 163–177; Albert C. Lewis, "The Building of the University of Texas Mathematics Faculty, 1883–1938", 205–239; Saunders Mac Lane, "The Education of Ph.D.s in Mathematics", 517–523.

3900. École Normale Supérieure. *Le centenaire de l'École Normale, 1795–1895.* Paris: Hachette, 1895. Ed. du Bicentenaire Paris: Presses de l'École normale superieure, 1994, 73 + xlv + 699 pp.

Useful history of the École Normale Supérieure. Contains a section on the teaching of mathematics at the school and lists of instructors and students. (Faculty included: Darboux, Duhamel, Goursat, Hermite, Lagrange, Laplace, and Tannery.) Also features portraits of mathematicians and an article on the "Influence of Galois on the Development of Mathematics" by Sophus Lie. A table of contents appears at the back of the book.

3901. École Polytechnique. *Livre du centenaire, 1794–1894.* Paris: Gauthier-Villars et Fils, 1895–1897. 3 vols.

Major source on the first century of the École Polytechnique. Volume 1 deals with mathematics and science; it includes an institutional history and biographical sketches of such polytechnicians as Cauchy, Chasles, Duhamel, Liouville, Poinsot, Poisson, and Serret. Especially striking are the portraits accompanying select biographies. A table of contents appears in each volume and a comprehensive name index is at the end of volume 3.

3902. Engel, Wolfgang. “Mathematik und Mathematiker an der Universität Rostock”. *Rostocker Mathematisches Kolloquium* No. 27 (1985), 41–105.

The author gives a historical survey concerning the case of mathematics and mathematicians at Rostock University, starting from the founding of the university in 1419. By far the largest part of the article is devoted to a detailed account of the teaching and research activities since 1946.

3903. Enros, Philip C. “The Analytical Society: Mathematics at Cambridge University in the Early Nineteenth Century”. Dissertation. University of Toronto, 1979. *Dissertation Abstracts International* A 40 no. 12, pt. 1 (June 1980), 6396-A.

A detailed study of a group of Cambridge undergraduates (1812–1813), including Babbage, Peacock, and Herschel, interested in promoting analytical mathematics. Establishes an intellectual and social framework for the Cambridge mathematical revival movement.

3904. Ermolaeva, N. S. “On the History of the St. Petersburg and Petrograd Mathematical Societies”. *Trudy Sankt-Peterburgskogo Matematicheskogo Obshchestva* 2 (1993), 309–322, 336.

The author gives full details of the administrative organization, membership, and early activities of the St. Petersburg Mathematical Society from the time of its founding in 1890 until 1900, after which records become poor. She also tells of the organizing of the Petrograd Physico-Mathematical Society in 1921 and its early activities. See review by R. L. Cooke in **MR** 95f:01036.

3905. Folta, Jaroslav. “Social Conditions and the Founding of Scientific Schools. An Attempt at an Analysis on the Example of the Czech Geometric School”. *Acta historiae rerum naturalium necnon technicarum.* Special issue 10 (1977), 81-179.

Embedded into a general methodological reflection about the notion of mathematical schools and their importance for historiography, the paper analyses the emergence and activities of the geometric school in the Czech provinces, mainly in the second half of the nineteenth century. It investigates internal and social conditions for the emergence of the geometric school and provides a detailed analysis of the productivity of the mathematicians in the school’s centers in Bohemia and Moravia.

3906. Fourcy, Ambroise. *Histoire de l’École Polytechnique.* Reprinted Paris: Belin, 1987, 199 pp.

This book, which is a reprint of the1828 original, still represents today the best account of the early history of the École Polytechnique, the famous French School institutionalizing a high level of mathematics and physics teaching. Fourcy’s book is organized in five chapters, presenting the development in chronological order.

The volume is enriched by excellent editorial work by J. Dhombres. In his introductory essay "The École Polytechnique and its Historians", he gives a critical account of the debates which accompanied the foundation and the development of the École and discusses its position in the French educational system. He has also added explanatory notes to Fourcy's text, a chronology on the main facts concerning the École up to 1982, and up-to-date bibliography of books and papers related to the history of the École and, last but not least, some 300 short biographies of persons mentioned by the author. All that recommends this welcome reprint as essential reading for all those interested in 19th-century mathematics and its institutions. See review by Umberto Bottazzini in **MR** 90b:01103.

3907. Francesconi, Stefano. "The Teaching of Mathematics at the University of Bologna from 1860 to 1940". In *Geometry and Complex Variables (Bologna, 1988/1990).* New York: Marcel Dekker, 1991 (Lecture Notes in Pure and Applied Mathematics, vol. 132), 415–474.

This paper analyses the institutional aspects of the history of modern mathematics in Italy. The author investigates the professional careers of the mathematics professors at the University of Bologna from 1860 to 1940 and changes in the curricula for mathematics students during that period. In the concluding sections, the development of the teaching in the mathematical faculty at Bologna, from the beginning of this century until World War II, is considered. Particularly useful are the appendices, with detailed tables of the mathematical courses scheduled year by year at the University including the corresponding professors and their academic status, from 1860 to 1940. See review by Umberto Bottazzini in **MR** 93d:01091.

3908. Frei, Günther. "Geschichte der Mathematik an der Universität Zürich und an ihren Vorläuferinstitutionen von ihren Anfängen bis 1914". In *Jahrbuch Überblicke Mathematik, 1994.* Braunschweig: Vieweg, 1994, 217-244.

A well-documented exposition of the development of mathematics at Zürich from its beginnings until 1914. It traces the predecessors of the University since humanism and the Reformation: the "Carolineum", a college founded in 1523 by the reformer Ulrich Zwingli, the further development in the 17th and 18th centuries and the reorganizations in the wake of the French Revolution and the Napoleonic era. This eventually led to its founding in 1833. The activity of many distinguished mathematicians at this institution is documented. See review by J. J. Burckhardt in **MR** 94m:01039.

3909. Frei, Günther, and Urs Stammbach. *Die Mathematiker an den Züricher Hochschulen.* Basel: Birkhäuser, 1994. 75 pp.

This book unites the individual papers by both authors, items 3908 and 3976 and gives a comprehensive presentation of the development of the mathematical teaching at the university and at the technical college. It is illustrated by numerous tables and by pictures of the mathematics professors.

3910. Frewer, Magdalene. *Das mathematische Lesezimmer der Universität Göttingen unter der Leitung von Felix Klein (1886-1922).* Köln: Bibliothekar-Lehrinstitut, 1979.

This thesis gives an overview of the development of libraries at seminars and institutes, the functional entities in German universities for specialized research and teaching. It analyzes in particular Felix Klein's innovative activities in transforming the hitherto dominating practice of rather private mathematical libraries controlled by omnipotent "Ordinarien" into effective reading rooms giving all mathematics students free access to the relevant literature. The first such institutionalization at Leipzig university in 1880 was followed by the famous reading room at Göttingen in 1886, which became the model institution for a generally intensified mathematical study. The thesis depicts the reading room's evolution up to the opening of the new Mathematical Institute in 1929, where a modern library system constituted the key resource for modern research and teaching.

3911. Gårding, Lars. *Matematik och matematiker.* Lund: Lund University Press, 1994, viii + 348 pp. Translated as *Mathematics and Mathematicians: Mathematics in Sweden before 1950.* Providence, R.I.: American Mathematical Society, 1998.

This book provides an able survey of the very rich mathematical activity in Sweden from the early eighteenth century to 1950. It is divided into sixteen chapters, focussing on individual mathematicians and their mathematics, on mathematical topics, and on the schools at Stockholm, Uppsala and Lund. There is a great deal of biographical and bibliographical information both on well-known figures and on relatively obscure individuals. A list of dissertations is given, too. See review by Thomas Archibald in **MR** 96a:01024.

3912. Gatto, Romano. *Tra scienza e immaginazione. Le matematiche presso il collegio gesuitico napoletano (1552-1670 ca.).* Firenze: Leo S. Olschki, 1994.

A detailed case study of the functioning of mathematics within the Jesuit College of Naples with an analysis of controversies in the related Jesuit province and in the entire Order about the role of mathematics within the Ratio Studiorum, the Jesuit syllabus.

3913. Gericke, Helmuth. "Zur Geschichte der Mathematik an der Universität Freiburg i.Br.". Freiburg: Beiträge zur Freiburger Wissenschafts- und Universitätsgeschichte, 1955.

Description of the changes of mathematics teaching at this tiny German university, spanning the period from its time as a Catholic university endowed with Jesuit lecturers to the modernization occurring relatively late in the 19th century. With lists of lecturers and professors.

3914. Gericke, Helmuth. "Aus der Chronik der Deutschen Mathematiker-Vereinigung". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 68 (1966), 46–74.

Relies upon previously unpublished documents to provide a thorough study of the association. See also Dauben, item 3150, 159–165, and Gutzmer, item 3926.

3915. Gericke, Helmuth. "Das Mathematische Forschungsinstitut Oberwolfach". In *Perspectives in Mathematics: Anniversary of Oberwolfach.* Edited by W. Jäger. Basel: Birkhäuser, 1984, 198–213.

Brief account of the history and organization of the mathematical research institute at Oberwolfach, founded by Wilhelm Süss in 1944. The article is partly based on a report written by Süss in 1953.

3916. Gispert, Hélène. "Features of the French Mathematics Development and the Higher Education Institutions (1860-1900)". In *'Einsamkeit und Freiheit' neu besichtigt.* Edited by Gert Schubring. Stuttgart: Franz Steiner Verlag, 1991, 198–213.

An analysis of the changes in the institutional structures in the France of the second half of the 19th century: the decline of mathematics within the École Poytechnique system and the expansion of the universitarian structures. Parallel changes in the disciplinary orientations within mathematics are documented.

3917. Gispert, Hélène. *La France mathématique.* Paris: Société Française d'Histoire des Sciences et des Techniques; Société Mathématique de France, 1991, 425 pp.

This book consists of two parts. The first part, written by H. Gispert, describes the development between 1870 and 1914 of the French Mathematical Society, which was officially created in 1872. The analysis deals with the creation of this society, the mathematical production of its members, the institutional revolutions in the 1880s, the evolution of mathematical production between 1880 and 1900, the ensuing new generation of mathematicians (Borel, Baire, Lebesgue). This part is complemented by statistical tables concerning members, mathematical production, etc. The second part consists of five additional articles, studying specific aspects of the changing mathematical productivity and its educational context. An appendix publishes the reports of 107 theses (1874–1900) and contains a description of the collection of the bibliographical data. See review by E. Knobloch in **MR** 96f:01040.

3918. Gispert, Hélène. "Les débuts des sociétés mathématiques en Europe". *Gazette des Mathématiciens* No. 53 (1992), 25–30.

The paper studies the processes which led to the foundation of mathematical societies in various European countries and discusses differences in their functions and structures. It is remarkable that the associations in the larger countries were established during the same period, and mainly by separation from more general associations for the exact sciences.

3919. Grattan-Guinness, Ivor. "The Società Italiana, 1782–1815: A Survey of its Mathematics and Mechanics". In *Symposia mathematica, Vol. XXVII (Cortona, 1983).* London, New York: Academic Press, 1986, 147-168.

The paper shows the importance of this society for the history of mathematics and its applications. Founded in 1782 to promote science, it became important for disseminating French approaches in the aftermath of the Revolution. The paper provides a survey of papers in mathematics and mechanics published in the first seventeen volumes of the society's journal *Memorie di matematica e di fisica*. These volumes extend to the year 1815. The history of the society and its journal is presented and relevant papers are identified and classified in a subsequent section. See review by Richard L. Francis in **MR** 87k:01077.

3920. Grattan-Guinness, Ivor. *Convolutions in French Mathematics, 1800-1840*. Basel: Birkhäuser, 1990. 3 vols.

This three-volume opus gives an in-depth analysis of the significant changes in French mathematics since the Revolution, in the Napoleonic era, and in the following Restoration period. It analyses, in particular, the interactions of physics with mathematics, presents short biographies of the major and minor scientists involved, and gives descriptions of the related institutional developments. Contains an exhaustive bibliography and rich indexes.

3921. Grattan-Guinness, Ivor. "France". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1430–1441.

An outline of the peculiar French institutional system: the parallelism of "Grandes Écoles" and universitarian structures, including its rise in the 18th century and during the French Revolution.

3922. Grattan-Guinness, Ivor. "Scandinavia". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2.

Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1472–1476.

A brief overview of the development of mathematics in Scandinavian countries, with some indications on institutional history.

3923. Grattan-Guinness, Ivor, and Roger Cooke. "Russia and the Soviet Union". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1477–1483.

A survey of the institutional development in Russia, focussing on the Petersburg Academy and the subsequent founding of universities.

3924. Grattan-Guinness, Ivor. "The British Isles". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1484–1494.

A survey of the development of mathematics at the two traditional English universities, Oxford and Cambridge, and of the expansion of the system during the 19th century, emphasizing the differences with Scotland in particular, and also with Wales and Ireland.

3925. Günther, Siegmund. *Geschichte des mathematischen Unterrichts im deutschen Mittelalter bis zum Jahre 1525*. Wiesbaden: Sändig, 1887. Reprinted 1969.

This is still the classical book on the history of mathematical teaching in Germany— understood as a broad geographical notion—during the Middle Ages. The study begins with first germs of institutionalized teaching established by Carolus Magnus and investigates all forms of institutionalization, including monasterial schools, parochial schools, and municipal schools, tracing in particular the emergence of the first universities in Germany and the slowly growing status of mathematics, as part of the quadrivium. Private forms of teaching by the "Rechenmeister" are dealt with in the last chapter.

3926. Gutzmer, August. "Geschichte der Deutschen Mathematiker-Vereinigung". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 10 (1909), 1–49.

Gutzmer's report on the foundation of the German Mathematical Society and its first years of functioning, made originally to the Third International Congress of Mathematicians in Heidelberg, 1904, was printed separately and in full by Teubner in 1904. For a more recent history of the German Mathematicians Union, see Gericke, item 3914, and Dauben, item 3150, especially pp. 159–165.

3927. Hensel, Susann. "Die Auseinandersetzungen um die mathematische Ausbildung der Ingenieure an den Technischen Hochschulen in Deutschland Ende des 19. Jahrhunderts". In *Mathematik und Technik* *im 19. Jahrhundert in Deutschland. Soziale Auseinandersetzung und philosophische Problematik*. Edited by S. Hensel, K.-H. Ihmig, and Otte. M.. Göttingen: Vandenhoeck und Ruprecht, 1989, 1–111, appendix.

Analysis of the "anti-mathematical" movement, peculiar to Germany: a movement within the German engineering fraternity of the 1890s challenging the function of mathematics within the technical colleges and claiming that the engineers themselves were capable of teaching future engineers the mathematics needed for their profession.

3928. Horiuchi, Annick. *Les mathématiques japonaises á l'époque d'Edo*. Paris: J. Vrin, 1994.

A study of the main mathematical schools in Japan, of their activity and social context, and of the most influential textbooks. In particular, two main practitioners of "wasan", the traditional Japanese form of mathematics, are presented: Seki Takakazu and Takebe Katahiro.

3929. Høyrup, Jens. "Influences of Institutionalized Mathematics Teaching on the Development and Organization of Mathematical Thought in the Pre-Modern Period". In *Studien zum Zusammenhang von Wissenschaft und Bildung*. Vol. 20. (Materialien und Studien des IDM.) Bielefeld: Institut für Didaktik der Mathematik der Universität Bielefeld, 1980, 7–137.

Investigation of the influence which institutionalized mathematics teaching exerted on the development, style, and cognitive organization of mathematical knowledge in varying sociocultural settings: Mesopotamia, Egypt, Classical Antiquity, India, Islam, and the Latin Middle Ages.

3930. Klemm, Friedrich. "Die Berliner Philomathische Gesellschaft (Philomathie)". *Sudhoffs Archiv* 42 (1958), 39–45.

Description of the founding and further activities of the Philomathische Gesellschaft in Berlin, a private association promoting the studies of mathematics and the sciences, during the decay of the Academy and in preparation of the founding of the later famous university.

3931. Knobloch, Eberhard. "Die Berliner Gewerbeakademie und ihre Mathematiker". In *E. B. Christoffel: The influence of his work on mathematics and the physical sciences*. Edited by P. L. Butzer and F. Fehér. Basel: Birkhäuser, 1981. 42-51.

The Gewerbeakademie was founded in 1821 by C. P. W. Beuth, reformer and organizer of Prussian polytechnical education, under the name of "Technisches Institut", becoming in 1827 "Gewerbe Institut". In 1879 it merged with a Berg- and a Bauakademie into the Technische Hochschule at Charlottenburg. From 1864 to 1879 Franz Reuleaux was director. Weierstrass stayed from 1856 to 1864 and was succeeded by S. Aronhold; among their disciples was H. A. Schwarz. Christoffel was at the Institut from 1869 to 1872. Among the other teachers of mathematics we find the painter Franz Pohlke (1810-1876) (of axonometry fame, 1860), Heinrich Weber, Hugo Ottomar Hertzer (1831-1908) and Paul du Bois-Reymond. Details are given on the relationship between Christoffel and the Institut, especially with Reuleaux. See review by D. J. Struik in **MR** 84b:01059.

3932. Knobloch, Eberhard. "Mathematics at the Berlin Technische Hochschule/Technische Universität: social, institutional, and scientific aspects". In *The History of Modern Mathematics*. Vol. II: *Institutions and Applications*. Edited by D. Rowe and J. McCleary. Boston: Academic Press, 1989, 251-284.

The Berlin Technische Hochschule was founded in 1879 by a merger of two considerably older academies, the Building Academy (1799) and the Vocational Training Academy (1821). In 1916 it also incorporated the former Mining Academy (1770). From the time of its inception, the Berlin Technische Hochschule was not only the leading technological training institution in Prussia, but throughout all of Germany as well. The study of its founding and development provides an interesting case study of the evolution of science policy. There was a conscious attempt on the part of the founders to involve mathematics, as both a cultural and a productive force (through its applications). Furthermore, the mathematicians of the Berlin Technische Hochschule played a crucial role when the Mathematical Society of Berlin was founded in 1901. The author traces the history of this institution up to the near present and discusses the interplay of ideas between the academic community, government officials, and mathematicians. See review by Pietro Nastasi in MR.

3933. Knobloch, Eberhard. "Knapp 300 Jahre Mathematik in Berlin: 1700–1993". In *Jahrbuch Überblicke Mathematik, 1994*. Braunschweig: Vieweg, 1994, 245-256.

The author presents a short but concise overview of the history of mathematics at Berlin. He distinguishes four institutional components: the Berlin Academy of Science, the university, the technical university and the Berlin Mathematical Society. After some remarks about the Berlin Mathematical Society, the article concludes with a short sketch of the processes dominated by political constraints after World War II. See review by Karl-Heinz Schlote in **MR** 95i:01024.

3934. König, Fritz. "Die Gründung des "Mathematischen Seminars" der Universität Leipzig". In *100 Jahre Mathematisches Seminar der Karl-Marx-Universität Leipzig*. Edited by H. Beckmann, and H. Schumann. Berlin: Deutscher Verlag der Wissenschaften, 1981, 41–71.

A detailed study of the founding of the Mathematical Seminar at Leipzig University, the first modernizing activity achieved by Felix Klein, and of the beginning of its functioning.

3935. Krayer, Albert. *Mathematik im Studienplan der Jesuiten. Die Vorlesung von Otto Catenius an der Universität Mainz (1610/11.* Stuttgart: Franz Steiner, 1991, 434 pp.

The book is a carefully designed case study on Jesuit mathematics teaching at a German Catholic university. It studies the changes in the organization of the Arts Faculty brought about by the taking over of teaching by the Jesuits from 1561. It analyzes the debates within the Jesuit Order about the role and conception of mathematics teaching within their "Ratio Studiorum". The main part of the article is the publication of the manuscript of the mathematics lecture taught at Mainz university in 1610/11 by the Jesuit Otto Catenius with added extensive comments. The lecture gives mathematical basics and proceeds to astronomical knowledge, backing Tycho Brahe's system.

3936. Lebesgue, Henri. "Les Professeurs de Mathématiques du Collège de France. Humbert et Jordan; Roberval et Ramus". *Revue Scientifique* 22 April (1922).

In this inaugural lecture at the Collège de France, Lebesgue describes the history of the mathematical chairs at this renowned teaching institution, in particular recounting the activities of four of his predecessors: P. Ramus, G. P. de Roberval, C. Jordan and Georges Humbert.

3937. Leimanis, Eugene. "Die Dorpater mathematische Schule in der zweiten Hälfte des 19. Jahrhunderts und die wissenschaftliche Tätigkeit ihrer ehemaligen Schüler, besonders am Polytechnischen Institut in Riga". In *Die Universitäten Dorpat/Tartu, Riga und Wilna/Vilnius 1579–1979.* Edited by G. von Pistolkohrs. Köln: Böhlau, 1987, 217-240.

The University of Dorpat (now Tartu) was founded in 1802 when Estonia was under Russian domination. The university, however, was German. This paper traces the development of mathematics as a process of specialization, as mathematics separated from astronomy. The culmination of mathematics was achieved by 1900 which was followed by a decline. Among the famous mathematicians active there, the paper mentions J. M. C. Bartels (1769–1836), Ferdinand Minding (1806–1885), Axel Harnack (1851–1888), and Adolf Kneser (1862–1930). In a second part, the work of two Dorpat disciples is studied. A third part gives an overview of the development of the Polytechnikum in Riga, Latvia, which was founded in 1862 and became the Polytechnic Institute in 1896, and of the activities of its mathematicians, who were largely graduates of the University of Dorpat. See review by D. J. Struik in **MR** 90g:01058.

3938. Lorey, Wilhelm. *Das Studium der Mathematik an den deutschen Universitäten seit Anfang des 19. Jahrhunderts.* Leipzig, Berlin: Teubner, 1916.

The classical study of the development of mathematics at the German universities during the 19th century. It set the standards for studies on the professionalization processes in modern disciplines. It combines the analysis of changes in mathematics teaching with institutional changes and changes in research patterns. The volume is complemented by extensive biographical and statistical information.

3939. van Maanen, Jan. "The Netherlands". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences.* Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1465–1471.

A survey of the mathematical and institutional development in the Netherlands, from the "Golden Age" in the 17th century to the decline in the 18th century, the changes brought about by the French period, and the late revival in the 20th century.

3940. Makdisi, George. *The Rise of Colleges. Institutions of Learning in Islam and the West.* Edinburgh: Edinburgh University Press, 1981.

An analysis of the functioning of institutions of learning, mainly of the madrasa, in the Islamic civilization, and of the disciplines taught and the modes of teaching. In particular, it discusses the role of the teaching of mathematics and the sciences within the madrasa system. The book concentrates on the Near East and gives a short comparison to the functioning of Christian universities in the Middle Ages.

A second book by Makdisi, *The Rise of Humanism in Classical Islam and the Christian West. With Special Reference to Scholasticism*, (Edinburgh, 1990), complements this book by investigating the movement of humanism, concerns with philology and literary arts, and their respective institutions.

3941. Manegold, Karl-Heinz. *Universität, Technische Hochschule und Industrie. Ein Beitrag zur Emanzipation der Technik im 19. Jahrhundert unter besonderer Berücksichtigung der Bestrebungen Felix Kleins.* Berlin: Duncker und Humblot, 1970.

The author traces the emergence of a system of technical education in Germany in the first half of the 19th century, independent of the university system, and its rise in social and scientific status during the second half of the century. While the technical colleges eventually challenged the supremacy of the universities, the role of mathematics between the two systems became critical. The book analyses Felix Klein's initiatives to overcome the institutional split and to establish relations between the sciences and technics. A particular focus of the study is the "Göttinger Vereinigung füer angewandte Physik und Mathematik", an association of scientists and industrialists which promoted technical applications within the universities.

3942. May, Kenneth O., ed. *The Mathematical Association of America: Its First Fifty Years*. Washington, D.C.: The Mathematical Association of America, 1972, vii + 172 pp.

This institutional history contains six essays: the background to the founding of the M.A.A. (P. S. Jones), its first quarter-century (C. B. Boyer), its role during the Second World War (E. P. Starke), and during the next two decades (H. F. Montague), as well as its financial history (H. M. Gehman). The final third of the volume consists of ten appendices, with data and brief histories on such topics as the *Mathematics Magazine* and the Putnam Competition, by G. H. Moore. Appendices list the constitution and by-laws, officers, committees, publications, films, Hedrick Lectures, national meetings, membership, awards, and competitions, as well as finances.

3943. Mehrtens, Herbert. "The 'Gleichschaltung' of Mathematical Societies in Nazi Germany". *Mathematical Intelligencer* 11 (3) (1989), 48-60.

The article studies how German mathematical societies behaved when faced with initiatives to force them into conformity with the National Socialist State—initiatives from within the society and from without. The main case is constituted by the "Deutsche Mathematiker-Vereinigung" (DMV) and the intitiatives of Ludwig Bieberbach to apply the "Führerprinzip" and to fight against "Jewish" mathematics. The GAMM (Gesellschaft für Angewandte Mathematik und Mechanik) and the "Mathematischer Reichsverband" are also discussed.

3944. Millán, Ana. "Governmental Scientific Institutions in Spain (1900-1936): The Laboratorio y Seminario Matemático." In *Science and Society in Contemporary Spain. Proceedings of the XVIIIth International Congress of History of Science 1989.* Vol. 6. (Cuadernos de Historia de la Ciencia.) Edited by Elena Ausejo. Zaragoza: Universidad de Zaragoza, 1990, 63-71.

The paper is a report on the first specialized center for mathematical research established in Spain in 1915, only shortly after mathematical training had started to be promoted by the government. This center became attached to the National Institute of Natural Sciences at Madrid and not to a university. Besides providing facilities for mathematical research, the center offered advanced teaching in mathematics thus leading students to the Ph.D. degree. The first and most influential director of The Laboratory and Seminar was Julio Rey Pastor who proved to contribute decisively to the development of mathematics in Spain.

3945. Müller, Conrad H. *Studien zur Geschichte der Mathematik, insbesondere des mathematischen Unterrichts an der Universität Göttingen im 18. Jahrhundert*. Dissertation. Göttingen: Universität Göttingen, 1904.

Reviewing the state of mathematics in Germany at the early 18th century, the study investigates the changes brought about in mathematical research and in teaching mathematics by the founding of Göttingen university—esteemed as the first "reformed" university paving the way for the modernization process.

3946. Ren Nanheng and Zhang Youyu, eds. *Historical Materials of Chinese Mathematical Society*. Nanjing, Jiansu (China): Jiangsu Education Press, 1995. x + 539

This book documents how the Chinese Mathematical Society promoted mathematical activities in China since its foundation in 1935. The first part covers the period of 1935 to 1948 where mathematics became adapted to international developments. The second part covers the period of 1949 to 1966 in which - after China becoming a People's dapted to international developments. The second part covers the period of 1949 to 1966 in which - after China becoming a People's Republic - mathematics became oriented on the model of the Soviet Union. During this period, the exclusive emphasis was on the practical features of mathematical studies and the strong concern on popularization. This period ends with the cultural revolution which caused a standstill in mathematical research and teaching. The third part deals with China's rejoining the international mathematical community, beginning in 1978, and establishing a firmer institutional basis for mathematics.

3947. Narasimhan, Raghavan. "The Coming of Age of Mathematics in India". In *Miscellanea Mathematica*. Edited by P. Hilton, F. Hirzebruch, and R. Remmert. Berlin: Springer, 1991, 235-258.

This paper traces the emergence of modern mathematics in India during the British colonial period. While part of the first universities founded by the British in the1850s, mathematics played only a minor part. The first innovative Indian mathematicians were those who had developed themselves by travelling to the European Continent and studying mathematics in France and/or in Germany. The gradual establishment of research traditions within the growing university system and the foundation of the first mathematical societies is reported and descriptions of the work of important mathematicians are given. The development culminated in the establishment of a research institute: the school of mathematics within the famous Tata Institute for Fundamental Research, founded in 1945. See review by Pradip Kumar Majumdar in **MR** 92j:01049.

3948. Ortiz, Luis Eduardo. "Spain, Portugal and Ibero-America, 1780-1930". In *Companion Encyclopedia of the History and Philosophy of the*

Mathematical Sciences. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1505-1511.

A comparative survey of the beginnings of mathematical institutions in Spain and Portugal and of the impact of the French structures after 1800, namely of the engineering school systems in Spain and in Ibero-America, and of the rise of mathematical institutions in the 20th centuries.

3949. Parshall, Karen H., and David Rowe. "The United States of America, and Canada". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1512-1525.

A survey of the institutional developments in North America, since the beginnings of Harvard to the founding of universities on a larger scale and the expansion in the 20th century.

3950. Pepe, Luigi, and Alessandra Fiocca. "La lettura di matematica nell'Universitá di Ferrara dal 1602 al 1771". *Annali dell'Universitá di Ferrara, Sezione VII - Science Matematiche* 31 (1985), 125-167.

The paper is the first part of an analysis spanning the entire history of the mathematical professorships at Ferrara university. For the second part see item 3952. During this early period, the university belonged to the Papal territories in Italy. The originally marginal role of mathematics within the Jesuit college was substantially extended after 1675 with a private professorship for teaching hydraulics to future engineers. Due to the regional and local permanent constraint of having to cope with flood control and irrigation, this additional obligation ensured a stable tenure for mathematics. The paper gives lists of the lecturers, of textbooks used, and related printed material.

3951. Pepe, Luigi, and Alessandra Fiocca. "L'Universitá e le scuole per gli ingegneri a Ferrara". *Annali dell'Universitá di Ferrara, Sezione VII - Science Matematiche* 32 (1986), 125-166.

This paper complements the authors' studies on mathematics at Ferrara University, items 3950, 3952. Supplementing the mathematical professorship with a lectureship for training engineers in 1675 not only considerably raised the status of mathematics within the university, but also paved the way for the new functions of mathematics as transmitted by the French when they dissolved the Papal territories, integrating them into French hegemony. Even after the restoration of the Papal States and even in the new Italian state since the 1860s, the linking between pure mathematics and the function of training engineers provided an innovative and productive pattern in institutionalization.

3952. Pepe, Luigi, and Alessandra Fiocca. "L'Insegnamento della Matematica nell'Universitá di Ferrara dal 1771 al 1942". In *Universitá e Cultura à*

Ferrara e Bologna. (Pubblicazioni dell'Universitá di Ferrara.) Firenze: Olschki, 1989, 1-78.

This second part of the authors' study on mathematics at Ferrara University (see item 3950 for the first part), deals with the impact of decisive external changes in structures and functions on the university—the dissolution of the Jesuit order, hegemony of the French educational system (transforming the university to a "Lycée"), restoration of the Papal territories, restructuring of the universities within the united Italian state, and Fascist change. Information on courses given and textbooks used is provided.

3953. Pepe, Luigi. "Mathematical Research and Academic Life in Bologna in the XVIIIth Century". In *Geometry and Complex Variables (Bologna, 1988/1990).* New York: Marcel Dekker, 1991 (Lecture Notes in Pure and Applied Mathematics, vol. 132), 291–305.

In this paper an overview is given of the development of mathematics at the University of Bologna during the eighteenth century. At the beginning of the century a group of young mathematicians, led by Giuseppe Verzaglia and Gabriele Manfredi enthusiastically devoted themselves to the study of the Leibnizian calculus and to its diffusion in Italy. Manfredi's book *De constructione aequationum differentialium primi gradus* (1707) was for decades one of the most important works in the field. At the same time the Accademia delle Scienze dell'Instituto was founded. During the middle of the century mathematics at Bologna was taught by Vincenzo Riccati, a son of the celebrated Count Jacopo Riccati and the author, with G. Saladini of the influential treatise *Institutiones analyticae* (1765–1767). At that time Bologna was one of the best centers for mathematical studies in Italy, but in the last decades of the century a long period of decline began. See review by Umberto Bottazzini in **MR** 93d:01089.

3954. Pitcher, Everett. *A History of the Second Fifty Years. American Mathematical Society: 1939-1988.* Providence, R.I.: American Mathematical Society, 1998, 346 pp.

The book gives an exhaustive description of the activities of the American Mathematical Society for its second fifty years: its officers, and in particular its presidents, its business meetings, the conferences organized, and the journals edited or supported. It is accompanied by data on membership evolution and financial issues and documents the services while the mathematical community was expanding considerably.

3955. Pucci, Carlo. "The Italian Mathematical Union from 1922 to 1944: Documents and Reflections". In *Symposia mathematica, Vol. XXVII (Cortona, 1983).* London, New York: Academic Press, 1986, 187-212.

In this paper, which is an important although brief study of the institutionalization of science in Italy, the author gives us a personal account of the first 22 years of the Italian Mathematical Union (Unione Matematica Italiana—UMI) from its foundation on 7 December 1922, to the collapse of the Fascist regime in Italy. The author relied on archives and documents of the UMI, on proceedings of congresses and on the collection of the *Bolletino dell'UMI*.

The paper is divided into an introduction plus six sections: 1. The foundation of the UMI; 2. The Congress of the International Mathematical Union in Bologna; 3. The *Bolletino dell'UMI* until 1943; 4. The congresses of the UMI; 5. The UMI and fascism; 6. Members and finances. See review by U. D'Ambrosio in **MR** 88a:01064.

3956. Pyenson, Lewis. *Cultural Imperialism and Exact Sciences: German Expansion Overseas 1900-1930.* New York: Lang, 1985.

This book, the first of a trilogy, studies how German applied mathematicians, physicists and astronomers came to staff major research and teaching institutions in Argentina, the South Pacific, and China. Its purpose is to investigate the relation between scientific development which requires observational institutional facilities overseas, and cultural and imperialist strategies of the state, in this case, Germany, backing the expansion of the research fields of their fellow scientists.

3957. Pyenson, Lewis. *Empire of Reason. Exact Sciences in Indonesia 1840-1940.* Vol. 13. (Brill's Studies in Intellectual History.) Leiden: Brill, 1989.

This second volume of the trilogy investigates the use of the exact sciences in Dutch foreign policy. In the Dutch East Indies, astronomy and physics received financial support from politicians and philanthropists in both the colony and the motherland. Examining pure learning in this colonial setting reveals a peculiar intertwining of the government, academic and private sectors. The book analyses the transmission of applied mathematics from the Netherlands and the development in particular of geophysics in Indonesia, by the founding of institutes, of observatories and even of the first universities.

3958. Pyenson, Lewis. *Civilizing Mission: Exact Sciences and French Overseas Expansion, 1830-1940.* Baltimore and London: John Hopkins University Press, 1993.

This book completes the trilogy devoted to cultural imperialism and exact sciences. It studies physicists and astronomers who worked in the French overseas empire (mainly in North Afrcia) and in French spheres of influence (e.g. in China). It documents institute building according to Western models on distant shores and also how pure knowledge played a role in the geopolitical contest. The relation between the expansion of learning overseas and the extension of political power is particularly striking in this French case.

3959. Reindl, Maria. *Lehre und Forschung in Mathematik und Naturwissenschaften, insbesondere Astronomie, an der Universität Würzburg von der Gründung bis zum Beginn des 20. Jahrhunderts.* Vol. Beiheft 1. (Quellen und Beiträge zur Geschichte der Universität Würzburg.) Neustadt a.d. Aisch: Degener, 1966, 287 pp.

The book includes a brief summary (including mathematics) of the general history of Würzburg University. The main part of the book presents all available bio-bibliographical information on the lecturers and professors who taught mathematics (and on physics and the other natural sciences disciplines as well).

3960. Rowe, David. "Klein, Hilbert, and the Göttingen Mathematical Tradition". In *Science in Germany. The Intersection of Institutional and Intellectual Issues.* Vol. 5. Edited by K. M. Olesko. OSIRIS (Second series), 1989, 186–213.

A thorough analysis of Klein's program to reorient mathematical teaching and research and of his successful forging of an alliance with Hilbert thus transforming Göttingen into the world's leading mathematical center at that time.

3961. Sayili, Aydin. *The Observatory in Islam and its Place in the General History of the Observatory.* (Publications of the Turkish Historical Society, Series VII, No. 38.) Ankara: Türk Tarih Kurumu Basimevi, 1960, xii + 429 pp.

The book begins with an evaluation of the role of the so-called secular sciences in Islamic civilization and of astronomy and astrology. In the main part, the functions of observatories in Islamic countries are discussed and the history of observatories in Islamic states is presented—from the first foundations during the reign of the Abbasid caliph Al-Mamun until the observatories of Samarkand and Istanbul. The different types of institutionalization are discussed. The work of prominent astronomers is studied as well.

3962. Schappacher, Norbert. "Das mathematische Institut der Universität Göttingen 1929-1950". In *Die Universität Göttingen unter dem Nationalozialismus.* Edited by H. Becker, H.-J. Dahms, and C. Wegeler. München: K. G. Saur, 1987, 345-373.

The paper documents the impact of National Socialism on the Mathematical Institute of Göttingen University, causing the dismissal of the greatest part of the Institute's important mathematicians in 1933. It analyzes the replacements at the vacant positions and how the Institute developed during the NS-time.

3963. Schappacher, Norbert, and Martin Kneser. "Fachverband - Institut - Staat". In *Ein Jahrhundert Mathematik 1890-1990. Festschrift zum*

Jubiläum der DMV. Edited by Gerd Fischer, et al. Braunschweig, Wiesbaden: Friedrich Vieweg, 1990, 1-82.

The paper depicts the foundation of the German Mathematical Association (DMV) in 1890 and extensively discusses the involvement of the DMV in the racist policy of the Nazi regime. The last chapter gives an overview of the developments after 1945, focussing on the institutionalization of research institutes: from the Oberwolfach center to the first "Sonderforschungsbereich" for mathematics (Bonn 1969) and eventually to the first Max-Planck-Institut for mathematics (Bonn 1981/82).

3964. Scharlau, Winfried. *Mathematische Institute in Deutschland: 1800–1945*. Freiburg: Deutsche Mathematiker Vereinigung; Braunschweig: Friedr. Vieweg & Sohn, 1990, vi + 291 pp.

This book is an important source for biographical and institutional information on the development of mathematics in Germany from 1800 onwards. It gives the complete list of mathematics professors of all chairs (i.e., "Ordinarien", but also the "Extra-Ordinarien") at the German universities and technical colleges/universities during this time. For each institution, there are five sections: A rough history of the institution; history of mathematics and related disciplines at the institution; the names of all professors, arranged by chairs; list of the "Habilitation" degrees conferred; list of all "Privatdozenten"; and bibliographical information.

The documentation is complemented by an essay by Gert Schubring giving an evaluation of the functional patterns of mathematical institutions in Germany and their change.

3965. Schönbeck, Jürgen. "Mathematik". In *Geschichte der Mathematik, der Naturwissenschaften und der Landwirtschaftswisenschaften*. Vol. 6. (Geschichte der Christian-Albrechts-Universität Kiel.) Edited by Karl Jordan. Neumünster: Wachholtz, 1968, 9-58.

Based on archival research, the author provides a detailed analysis of the evolution of mathematics teaching at the tiny Kiel university, which belonged until 1867 to Denmark and then was incorporated into Prussia. During the Danish period, mathematics—as part of the minor ranking Arts Faculty— had a preparatory function for "higher" studies and was mostly taught by professors who were also in charge of quite a number of other, unrelated disciplines. Decisive structural changes were begun in the 1870s, in the wake of the Prussian reorganization. Biographical information on the mathematics professors is given.

3966. Schöner, Christoph. "Mathematik und Astronomie an der Universität Ingolstadt im 15. und 16. Jahrhundert". Berlin: Duncker und Humblot, 1994.

Despite its humble title, this book provides not only a case study of the transition from the medieval functioning of mathematics to the early modern times, but it provides at the same time a systematical comparison of the status and functioning of mathematical teaching at European universities in the Middle Ages. In the case of Ingolstadt university, the territorial university of Bavaria, later transferred to Landshut and eventually to Munich, intriguing processes are carefully analyzed: first the transition to modernizing humanism and then its suppression by the Catholic Counter-Reformation. For a certain period, there were two rivalling Arts faculties, both with different mathematical programs. The book ends with the Jesuit victory and the replacement of the mathematics professorship by Jesuit lecturers.

3967. Schubring, Gert. "Die Entwicklung des Mathematischen Seminars der Universität Bonn 1864–1929". *Jahresbericht der Deutschen Mathematiker-Vereinigung* 87 no.4 (1985), 139–163.

The paper analyses the structural development of mathematics at Bonn university, from a minor discipline subordinated to physics to the founding of a Seminar specializing in pure mathematics, which developed in an analogous manner to other German mathematics institutes. Functional changes in teacher education are shown to have induced disciplinary expansion. See review by H.-J. Vollrath in **MR** 87d:01036.

3968. Schubring, Gert. "Das Mathematische Seminar der Universität Münster, 1831/1875 bis 1951". *Sudhoffs Archiv für Geschichte der Medizin und der Naturwissenschaften* 69 no. 2 (1985), 154–191.

The history of mathematics at the University of Münster is described as a case study of the rise of mathematics as a discipline and its subsequent development and differentiation. The case of Münster is particularly intriguing since this former Catholic university had to adopt the model of the northern German, Protestant universities during the first half of the nineteenth century: the dual role of teaching and research and the seminars being the institutional expression of this duality. Thus, one can see in Münster emerging what constituted the kernel of the famous Prussian university reform: it was the independence of the Philosophical Faculty by means of the formation of a new career path, the profession of the Gymnasium teacher. The emergence of mathematics as a discipline was an integral part of this process of attaining independence. The subsequent development of mathematics is a consequence of its status between the humanities and the exact sciences with regard to its function for teacher training. The different stages of development are described by means of largely unknown archival sources. See review by M. Kline in **MR** 87f:01101.

3969. Schubring, Gert. “Pure and Applied Mathematics in Divergent Institutional Settings in Germany: the Role and Impact of Felix Klein”. In *The History of Modern Mathematics*. Vol. II: *Institutions and Applications*. Edited by D. Rowe, and J. McCleary. Boston: Academic Press, 1989, 171–220.

An analysis of the complex institutional structure for mathematical research and teaching throughout the nineteenth century in Germany, due to the multitude of different German states and their varying cultural policies, as well as the institutional split between pure and applied learning, and of Klein’s initiatives to establish a modernized balance.

3970. Schubring, Gert. “Zur strukturellen Entwicklung der Mathematik an den deutschen Hochschulen 1800-1945”. In *Mathematische Institute in Deutschland 1800-1945*. Edited by W. Scharlau. Braunschweig: Vieweg, 1990, 264–278.

A survey of the functional changes of mathematics teaching at German universities and technical colleges and of the induced institutional changes. The institutional kernel for later expansion proved to be the “Seminar”: it constituted the focus for the functional relations between professional and career structures of the persons to be formed, institutional patterns of formation, content and forms of teaching and their impact on styles of research, and professional structures of the teaching and research staff itself. Not until the Weimar period did the Seminar model become outdated and be replaced by an expanded Institute model which was generally applied only after 1940. A decisive expansion to a department structure was only realized in the 1960s.

3971. Schubring, Gert. “Germany to 1933”. In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. 2. Edited by I. Grattan-Guinness. London and New York: Routledge, 1994, 1442-1456.

A survey of the transformation of mathematics at German universities from an encyclopedic endeavour to a specialized modern discipline—first enhanced at the two reform universities Halle and Göttingen, then realized at the Prussian universities in the first half of the 19th century. The paper describes the adoption of the “research ethos” and its dissemination to the other German states, and ends with the frictions caused by the modernization process.

3972. Schubring, Gert. “Changing Cultural and Epistemological Views on Mathematics and Different Institutional Contexts in 19th Century Europe”. In *L’Europe mathématique–Mythes, histoires, identités*. (†Mathematical Europe–Myths, History, Identity†.) Edited by

C. Goldstein, J. Gray, and J. Ritter. Paris: Éditions de la Maison des Sciences de l'Homme, 1996, 361–388.

A comparative study of the differences in the institutional and conceptual development of mathematics in several European states, in particular France and Germany, with some consideration also given to England, Italy, and Greece. This paper proposes a theoretical framework for undertaking comparisons.

3973. Sédillot, L. *Les professeurs de mathématiques et de physique générale au Collège de France. Avec des notes de B. Boncompagni.* Roma: Imprimerie des sciences mathématiques, 1869, 204 pp.

This is a detailed study of the functioning of mathematics teaching at the Collège Royal, renamed Collège de France after the Revolution, and of its mathematics professors according to the different "chaires". The study is organized into four parts: the period of foundation 1530-1547; the period 1547-1589, largely marked by the activity of Petrus Ramus; the period 1589-1774; and the period 1774-1869.

3974. Shinn, Terry. "The French Faculty System, 1808-1914: Institutional Change and Research Potential in Mathematics and the Physical Sciences". *Historical Studies in the Physical Sciences* 10 (1979), 271–332.

A sociological study of research productivity in the physical sciences and in mathematics within the science faculties, from the time of establishment of these quasi-universitarian but low status structures, to the time of their expansion in the last third of the 19th century.

3975. Siegmund-Schultze, Reinhard. "Berliner Mathematik zur Zeit des Faschismus". *Mitteilungen. Mathematische Gesellschaft der Deutschen Demokratischen Republik* No.4 (1987), 61–84.

The paper chiefly discusses the situation and fate of the Institute for Applied Mathematics in Berlin (whose first director was von Mises) and the "Mathematical Seminar" (later Institute) under the Nazi regime. Although von Mises and Stefan Bergmann had to leave Germany,one might nevertheless have expected the Nazi regime to have supported applied mathematics (with "politically and racially appropriate" personnel). On the contrary, the institute at Berlin declined almost to the vanishing point. As to "pure mathematics" (the Mathematical Seminar), it was almost totally controlled during the period by Ludwig Bieberbach. The author argues that Bieberbach's attitudes led to decline. A final section discusses Erhard Schmidt as an example of the problem of the resistance to fascism by "unpolitical" right-wing intellectuals. See review by S. L. Segal in **MR** 90a:01103.

3976. Stammbach, Urs. "Geschichte der Mathematik an der ETH Zürich, 1855–1932". In *Jahrbuch Überblicke Mathematik, 1994*. Braunschweig: Vieweg, 1994, 194-216.

The article describes the early developments of the prestigious institution created in 1855 as Eidgenössische Polytechnische Schule and called Eidgenössische Technische Hochschule (ETH) after 1911. The Zürich activities of great mathematical figures are traced, and brief accounts of their scientific achievements are added: Raabe, Dedekind, Christoffel, H. A. Schwarz, Weber, Frobenius, Hurwitz, Minkowski, M. Grossmann, Weyl, Plancherel, Polya, Gonseth, and H. Hopf. The first International Congress of Mathematicians took place in Zürich in 1897; the author ends his study in 1932, when Zürich hosted that meeting for the second time at a time when Europe was heading towards political turmoil. See review by Jean-Paul Pier in **MR** 94k:01036.

3977. Taton, René, ed. *Enseignement et Diffusion des Sciences en France au XVIIIe Siècle*. Paris: Hermann, 1986, 778 pp.

This book is a seminal collection of authoritative essays on all the important aspects of teaching mathematics, sciences and technology in France at the secondary and higher education levels. In particular, the split between university teaching and the growing technical and military sector is amply documented. Of particular importance for mathematics are the papers on the military schools, an engineering school, and the observatories: R. Hahn, "L'enseignement scientifique aux écoles militaires et d'artillerie", 513-546; R. Taton, "L'École du Génie de Mézières", 559-615; R. Hahn, "Les observatoires en France au XVIIIe siècle", 653-658.

3978. Tobies, Renate. "Zur Geschichte deutscher mathematischer Gesellschaften". *Mitteilungen der Mathematischen Gesellschaft der DDR* 2-3 (1986), 112-134.

Based on her doctoral thesis, the author describes the processes leading to the foundation of the "Deutsche Mathematiker-Vereinigung" and gives an overview of its activities. Of other German mathematical associations included, the "Göttinger Vereinigung fü r angewandte Physik und Mathematik" is depicted with special emphasis.

3979. Tobies, Renate. "On the Contributions of Mathematical Societies to Promoting Applications of Mathematics in Germany". In *The History of Modern Mathematics*. Vol. II: *Institutions and Applications*. Edited by D. Rowe, and J. McCleary. Boston: Academic Press, 1989, 223–248.

A study of the rise of applied mathematics as promoted by the Deutsche Mathematiker-Vereinigung and the Göttinger Association for Applied Physics and Mathematics and of key figures in this process, like F. Klein, C. Runge and L. Prandtl.

3980. Toepell, Michael. *Mathematiker und Mathematik an der Universität München. 500 Jahre Lehre und Forschung*. Vol. 19. (Algorismus.) München: Institut für Geschichte der Naturwissenschaften, 1996, xx + 519 pp.

The book gives a longitudinal study of mathematical teaching at the major territorial university of the German state of Bavaria: first located at Ingolstadt (1472-1799), then at Landshut (1800-1826), and eventually at Munich (since 1826). The author gives a "global" summary for the periods 1472 to 1850 and 1925 to 1992, concentrating on bio-bibliographical information on lecturers and professors and in particular on used textbooks. The period 1850 to 1925 he treats "locally", with more detailed analysis of the functioning of teaching and by documenting the policy of staff recruitment. In fact, this period saw the decisive reforms when the Prussian conceptions of disciplinary autonomy were implemented.

3981. Uebele, Hellfried. *Mathematiker und Physiker aus der ersten Zeit der Münchener Universität. J. L. Späth, Th. Siber und ihre Fachkollegen*. Dissertation. München: Universität München, 1972.

An analysis of mathematical teaching at Munich university and of the mathematical conceptions and publications of the mathematics professors in the first half of the 19th century, like Th. Siber, J. L. Späth, and C. Stahl

3982. Velamazan, Angeles. *La Enseñanza de las Matemáticas en las Academias Militares en España en el Siglo XIX*. Vol. 7. (Cuadernos de Historia de la Ciencia.) Madrid: Siglo XXI de España Editores, 1994.

The book gives an analysis of the role and practice of mathematical studies within the training of military personnel and of engineers at the Spanish military academies during the nineteenth century. These institutions prove to have provided the most extensive basis for the development of mathematics during this century. The author gives an overview of the evolution of the military training and the status of mathematics within it in the preceding centuries. Numerous appendices document the mathematical curricula, the textbooks used and the entrance and leaving requirements for the different military corps and engineers.

3983. Volk, Otto. "400 Jahre Mathematik und Astronomie an der Universität Würzburg: Alma Julia Herbipolensis 1582-1982". *Celestial Mechanics* 28 (1982), 243-250.

The paper gives a brief summary of the evolution of mathematics teaching at Würzburg University from its foundation in 1582. Changes in the structure of this originally Jesuit university are reported and the work of major mathematicians who taught there is mentioned.

3984. Wollmershauser, Friedrich R. “Das Mathematische Seminar der Universität Strassburg, 1872–1900”. In *E. B. Christoffel: The influence of his work on mathematics and the physical sciences*. Edited by P. L. Butzer and F. Fehér. Basel: Birkhäuser, 1981, 52-70.

As an introduction, the author outlines the history of the ancient universities of Strasbourg until 1872. After the French-German war of 1870-71, Alsatia was annexed to the German empire, and in 1872 the so-called “Kaiser-Wilhelms-Universität” was opened in Strasbourg. The “Mathematisches Seminar”' or Mathematical Section of the University was directed by Elwin Bruno Christoffel and Theodor Reye. Cooperators until about 1900 were Georg Roth, Eugen Netto, Carl Schering, Adolf Krazer and Heinrich Weber. Some information is given about the working conditions and the number of students. See review by P. Bockstaele in **MR** 84e:01101.

SOCIOLOGY OF MATHEMATICS

3985. Benoit, P., K Chemla,. and J. Ritter, eds. *Histoire des fractions, fractions d'histoire*. Basel: Birkhauser, 1992.

Examines the variety of social contexts of the origins and development of fractions.

3986. Bishop, A. J. *Mathematical Enculturation*. Dordrecht: Kluwer, 1988.

Describes mathematics as "a way of knowing" and analyses the educational consequences of the cultural perspective. The notion of mathematics as a cultural product and the environmental and societal activities which stimulate mathematical concepts together with the cultural values which mathematics embodies are considered. In identifying the five "universal" aspects of mathematics in a variety of cultures: counting, locating, measuring,designing, playing and explaining; Bishop draws from these studies consequences for the design and implementation of school curricula and teacher training.

3987. Bloor, David. *Knowledge and Social Imagery*. London: Routledge and Kegan Paul, 1976, 156 pp. second edition 1991.

Discussion of the "strong programme in the sociology of knowledge"; application to mathematics: J. S. Mill vs. Frege, numbers, "negotiation" of logic and proof, Azande logic. A new chapter in the second edition answers critics of the "strong programme in the sociology of knowledge". For a critique of the general approach see S. Woolgar, "Interests and Explanation in the Social Study of Science", *Social Studies of Science* 11 (1981), 365–394.

3988. Bloor, David. "Wittgenstein and Mannheim on the Sociology of Mathematics". *Studies in the History and Philosophy of Science* 4 (1973), 173–191.

Takes Wittgenstein's philosophy of mathematics to defeat mathematical realism as a major obstacle to a sociological analysis of mathematics.

3989. Bos, H. J. M., and H. Mehrtens. "The Interactions of Mathematics and Society in History. Some Exploratory Remarks". *Historia Mathematica* 4 (1977), 7–30.

Survey; discussion of social forms of mathematical practice, bibliography.

3990. Bos, H. J. M. "Mathematics and its Social Context: A Dialogue in the Classroom with Historical Episodes." *For the Learning of Mathematics* 4 (1984), 2–9.

Argues for the social influences on the devlopment of mathematical concepts. Examples taken from High School mathematics.

3991. Crane, Diana. *Invisible Colleges: Diffusion of Knowledge in Scientific Communities*. Chicago: The University of Chicago Press, 1972, 213 pp.

Structural and quantitative analysis of scientific communication in two specialities, one being the theory of finite groups; no concern for the mathematical contents of the theory.

3992. Crowe, M. "Ten 'Laws' Concerning Patterns of Change in the History of Mathematics". *Historia Mathematica* 2 (1975), 161–166.

Discussion and critique of Wilder's (1968) list of "Laws" of the evolution of mathematics.

3993. Crump, T. *The Anthropology of Numbers*. Cambridge: Cambridge University Press, 1990.

Sets out to establish the place of number in cultural life. Covers the social and anthropological significance of number in language, cosmology and ethnoscience, economy, society, politics, measurement, comparison, equivalence, time, money, games of chance, music, poetry, dance, art and architecture. Ten pages of bibliography.

3994. D'Ambrosio, U. *Socio-Cultural Bases of Mathematics Education*. Campinas, Brazil: UNI-CAMP, 1985.

Detailed discussion and critique of the contemporary social and political contexts of mathematics education from the father of "ethnomathematics".

3995. Dowling, P. *The Sociology of Mathematics Education*. London: Falmer, 1998.

Radical view challenging received myths about mathematics and mathematics education. Social activity theory. Diverse and changing relationship between mathematical and other practices and the need for those involved in education to evaluate rigorously and sociologically the schemes and textbooks used in classrooms.

3996. Dowling, P., and R. Noss, eds. *Mathematics Versus the National Curriculum*. London: Falmer, 1990.

Response to the imposition of a National Curriculum in Mathematics in England and Wales by the Conservative Minister of Education, Richard Baker in 1989. Critique of fundamental assumptions and social consequences of politicians' simplistic conceptions of mathematical knowledge, its purposes and its uses.

3997. Fang, J., and K. P. Takayama. *Sociology of Mathematics. A Prolegomenon*. Hauppauge: Paideia Press, 1975, 364 pp.

Written by Fang, not a sociologist, to provide an interdisciplinary "meeting place" for studies on mathematics. A (very) preliminary survey of problems of method and theory in social aspects of the history and philosophy of mathematics, presented on the background of a personal philosophy of the "working mathematician." Special topics: Greek mathematics, critique of Fisher, items 3998, 3999, Japanese mathematics (Wasan), non-Euclidean geometry.

3998. Fisher, Charles S. "The Death of a Mathematical Theory". *Archive for History of Exact Sciences* 3 (1966), 137–159.

Claims that invariant theory is subsumed by Hilbert's espousal of a generalised abstract group theory.

3999. Fisher, Charles S. "The Last Invariant Theorists". *Archives Européennes de Sociologie* 8 (1967), 216–244.

Study of the fate of a mathematical theory, "theory" being taken as a social entity.

4000. Fisher, Charles S. "Some Social Characteristics of Mathematicians and Their Work". *American Journal of Sociology* 78 (1972/1973), 1094–1118.

Case study of types of professional behavior in problem-solving, along with the history of the Poincaré conjecture.

4001. Folta, Jaroslav. "Social Conditions and the Founding of Scientific Schools. An Attempt at an Analysis on the Example of the Czech Geometric School". *Acta historiae rerum naturalium necnon technicarum. Czechoslovak Studies in the History of Science* Special Issue 10. Prague: Czechoslovak Academy of Sciences, 1977, 81–179.

Starting from a general discussion of mathematical "schools," the development of Czech mathematics is shown to be conditioned by the social and economic conditions generated by the onset of the industrial revolution in this region.

4002. Forman, Paul. "Weimar Culture, Causality, and Quantum Theory, 1918–1927. Adaption by German Physicists and Mathematicians to a Hostile Intellectual Environment". *Historical Studies in the Physical Sciences* 3 (1971), 1–115.

Analysis of the reaction of scientists to "environmental pressure" from the antirationalist intellectural milieu of Weimar Germany as a source of receptivity for a new, acausal theory.

4003. Gillies, D., ed. *Revolutions in Mathematics.* Oxford: Clarendon Press, 1992.

A collection of papers inspired by the debate between Crowe (there are no revolutions) and Dauben (revolutions do occur). The original papers, published between 1975 and 1984, appear in this volume and are then followed by a number of interesting points of view which take one side or the other or, more diplomatically, find the middle ground. Whether or not revolutions occur in mathematics seems, from this collection, to depend upon how one interprets "revolutions", and whether one takes a broadly "internalist" or "externalist' point of view. While the different papers argue these positions, it is clear that the discussion is also about the individuals' different approaches to historiography. Extensive bibliography of 22 pages covers original sources, studies in interpretation of history of mathematics and social, cultural and philosophical influences.

4004. Griffiths, B., and A. G. Howson *Mathematics, Society and Curricula*. Cambridge: Cambridge University Press, 1974.

A seminal study of the relations between school mathematics and the social and political determinants of curricula. Most examples are taken from English contexts although reference is made to mathematics curriculum projects in the USA and the influence of the "New Mathematics". The work contains some case studies of "typical" curricula and their development, but virtually no sociological analysis.

4005. Hacking, I. *The Taming of Chance*. Cambridge: Cambridge University Press, 1990.

The discussion covers the period from the early nineteenth century to the earlier part of this century. Hacking's philosophical aims are to seek out the conditions that made possible our present organization of concepts in the two areas of physical indeterminism and statistical information developed for purposes of social control. The discussions cover the emergence of probability theory and the use of statistics linked to insurance, social policy, the invention of normalcy, eugenics, and the power of the state. Hacking shows how the ideas of "mere chance" became fashioned into a tool for social and political control. Notes, references and bibliographical information.

4006. Hessen, Boris. "The Social and Economic Roots of Newton's *Principia*". In *Science at the Cross Roads*. Edited by N. I. Bukharin, et al. London: Kniga Ltd., 1931. New ed. London: F. Cass & Co., 1971, 149–212. Separate ed. New York, 1971.

The classical externalist interpretation of Newton's achivements from an orthodox Soviet-Marxist point of view, relating science directly to class struggle and the development of means and modes of production; not specific for mathematics.

4007. Høyrup, J. *In Measure, Number and Weight, Studies in Mathematics and Culture*. New York: SUNY Press, 1994.

A collection of previously published papers putting forward some strong arguments supporting the social contexts of mathematical invention. Covers a range of subjects and periods from Mesopotamia, Greece, Islam, the Middle Ages and the Renaissance. The final chapter considers the past and current implications of the military involvement in the mathematical sciences.

4008. Kahane, J., ed. *Mathematics for the 1990s.* Cambridge, 1987.

Discussion of social, political and economic aspects which are used to pose a number of questions about different possible kinds of mathematics curricula.

4009. Lakatos, I. *Proofs and Refutations.* Cambridge: Cambridge University Press, 1976.

An attack on the traditional approach to the history and philosophy of mathematics based on the fallibilism of Popper and the heuristic problem-solving approach of Polya. The simulated classroom discussion on the discovery of the so-called "Euler formula" for polyhedra draws on a wide background of social and historical information covering mathematics and science and emphasizes new and important social contexts of the process of discovery. Other aspects of his theme clearly locate the construction of mathematics and its proofs in particular metaphysical contexts and problem situations, leading to serious criticisms of the historiography of many versions of the history of mathematics current at that time.

4010. MacKenzie, Donald A. *Statistics in Britain 1865–1930. The Social Construction of Scientific Knowledge.* Edinburgh: Edinburgh University Press, 1981, 306 pp.

Detailed and well-based account on the rise of statistical theory in Britain (Galton, Pearson, Fisher), arguing for the social construction of scientific contents on the background of social interests connected with the contemporary eugenics movement.

4011. MacLeod, Roy. "Changing Perspectives in the Social History of Science". *Science, Technology and Society: A Cross-Disciplinary Perspective.* Edited by I. Spiegel-Rösing, and D. de Solla-Price. London: Sage, 1977, 149–195.

General survey; bibliography.

4012. Mehrtens, Herbert, H. J. M. Bos, and I. Schneider, eds. *Social History of Nineteenth Century Mathematics.* Boston: Birkhäuser, 1981, 301 pp.

Thirteen papers of varying length, method, and aim from a workshop, Berlin 1979. Three parts: "aspects of a fundamental change—the early nineteenth century," "the professionalization of mathematics and its educational context," "individual achievements in social context," and an appendix, including a general paper and select bibliography.

4013. Needham, Joseph. "Mathematics and Science in China and the West". *Science and Society* 20 (1956), 320–343. Reprinted in *Sociology of*

Science; Selected Readings. Edited by B. Barnes. Harmondsworth: Penguin Books, 1972, 21–44.

Comparative analysis of the sources of the "scientific revolution" of the Renaissance: "Apparently a mercantile culture alone was able to do what agrarian bureaucratic civilisation could not—bring to fusion point the formerly separated disciplines of mathematics and nature knowledge.

4014. Needham, J. *Science and Civilisation in China.* Vol. 3. *Mathematics and the Sciences of the Heavens and the Earth.* Cambridge: Cambridge University Press, 1959.

Claims that the Chinese failure to exploit and extend the mathematics they developed was due to environmental, ecological and sociocultural factors. Mathematics was very practical and connected with concrete problems while the social background was intimately connected with the establishment and operation of the calendar. In addition, there was no conception of the "laws of nature" as in Western science, and so no perceived regular occurrences to investigate using mathematics. Only a mercantile culture could stimulate mathematical development by encouraging the connection between the mercantile and intellectual interests in society.

4015. Pedersen, Olaf. "The 'Philomaths' of 18th Century England". *Centaurus* 8 (1963), 238–262. Peter J. Wallis "British Philomaths—Mid-Eigtheenth Century and Earlier". *Centaurus* 17 (1972/1973), 301–314. Peter Wallis, and Ruth Wallis. "Female Philomaths". *Historia Mathematica* 7 (1980), 57–64.

Studies of a group of minor mathematicians and mathematical laymen important for the dissemination of mathematical knowledge. See also item 4762.

4016. Price, M. H. *Mathematics for the Multitude? A History of the Mathematical Association.* Leicester, England: The Mathematical Association, 1994.

Originally founded as the Association for the Improvement of Geometrical Teaching in 1871, it became the Mathematical Association in 1897 and first published its journal the *Mathematical Gazette* in 1894. There is information on the organization itself; the individual professional mathematicians, mathematics teachers and government officials concerned; its curriculum development publications; text books and their authors and the relation of the Mathematical Association with other organizations representing Teachers and Inspectors of Mathematics. The final chapter deals with the centralisation of the curriculum and the political control imposed in England as a consequence of the perceived "deficiencies" indicated in international mathematical testing. Notes, references and bibliography.

4017. Restivo, S. *The Social Relations of Physics, Mysticism and Mathematics*. Dordrecht: Reidel, 1985. Studies in Social Structure, Interests and Ideas; originally published in the series Episteme, Vol. 10, 1983.

Advocates a "broadly conceived and flexible materialist sociology of knowledge" (p. viii) in physical science and mathematics. Claims that Marx is the founder of the sociology of science. The first part of the book considers the holistic views of reality and the paradoxes, like wave and quantum theory, that have resisted logical resolution in physics and discusses epistemic strategies as social constructions. The second part is devoted to a consideration of the social roots of mathematics and describes the slow development of interest in the sociology of mathematics showing how Spengler's work was largely neglected. Source book for critiques of internal/external influences on mathematics and its social contexts, Marxism and materialism. Notes and references containing a wealth of bibliographical information.

4018. Restivo, S. *Mathematics in Society and History*. Dordrecht, Boston, London: Kluwer, 1992.

Spengler's "weak" sociology of mathematical traditions is taken as a basis for a discussion of the contexts of the growth of mathematical practices, the actors, and their purposes in China, Arabia-Islam, India, Japan and Europe. Social activities in everyday life give rise to "classical" forms of mathematics, arithmetic and geometry, and the media in which these ideas are expressed, and the power relations of the parties involved are considered. The "strong" sociology of mathematics is discussed and a critique of "pure" mathematics is developed from the point of view that the concept of mind is a social structure, and that levels of abstraction, theory and purity are also therefore functions of a social nature. Sociology of mathematics from a basically Marxist-Durkheimian point of view. Name and subject indexes, appendices, notes and bibliography.

4019. Restivo, S., J. P. Van Bendegem, and R. Fischer, eds. *Math Worlds: Philosophical and Social Studies of Mathematics and Mathematics Education*. New York: SUNY Press, 1993.

Philosophy, politics, gender, social contexts and social changes are provocatively discussed by a number of contributors.

4020. Richards, J. *Mathematical Visions: The Pursuit of Geometry in Victorian England*. Boston: Academic Press, 1988.

Discussion of how the concepts of geometrical reality and truth were located in the wider contexts of moral and social beliefs of the time.

4021. Schneider, Ivo. "Der Einfluss der Praxis auf die Entwicklung der Mathematik vom 17. bis zum 19. Jahrhundert". *Zentralblatt für Didaktik der Mathematik* 9 (1977), 195–205.

Presents examples of the influence of social practice on the development of mathematical knowledge from Galilei to the *École Polytechnique*. See also item 2106.

4022. *Social Studies of Science*. 8, No. 1 (February 1978): Special Theme Issue: *Sociology of Mathematics*.

MacKenzie, D. and B. Norton on Karl Pearson and statistics in intellectual and social context; B. Martin on game theory; N. Stern on age and achievement.

4023. Struik, Dirk J. "On the Sociology of Mathematics". *Science and Society* 6 (1942), 58–70.

Classical Marxist view of history of science consistently locating the development of mathematics in its social and historical contexts. Theorems correspond to the real world outside our consciousness and that mathematical results are generally reached by an inductive process. There are general laws of social development and it is possible to provide a consistent materialist account of society and mathematics where institutions, bureaucracies and organizations are part of the social context in which mathematics develops.

4024. White, L. A. "The Locus of Mathematical Reality: An Anthropological Footnote". *Philosophy of Science* 14 (1947), 289–303. Reprinted in J. R. Newman, ed. *The World of Mathematics*. Vol 4. London, 1956, 2348–2364, item 104.

Introduces an anthropological analysis and talks about "mathematical behavior" in terms of a particular kind of "symbolic activity" as a subset of general cultural activity, suggesting that the objectivity of mathematics lies within individual culture. He distinguishes between mathematics existing as a culture, somehow as an independent entity, and mathematics existing in a culture, from which mathematical ideas enter our minds. These ideas were taken up and elaborated by Wilder, item 907.

4025. Wilder, R. L. *Mathematics as a Cultural System*. New York and Oxford: Pergamon, 1981.

A development of earlier ideas published in the *Evolution of Mathematical Concepts* (1968) (item 907) Influenced by the anthropological theories of White, Wilder organizes his analysis around the concept of mathematics is a specialized symbol system, and introduces the ideas of environmental stress, hereditary stress and cultural stress. The culture of mathematics is seen as some kind of organic entity having its own evolutionary laws where the changes are implemented by the stresses and a series of "laws" or principles are postulated which govern the evolution of mathematics.

4026. Wittgenstein, L. *Remarks on the Foundations of Mathematics*. Cambridge, MA: MIT Press, 1967.

4027. Wittgenstein, L. *Wittgenstein's Lectures on the Foundations of Mathematics*. Sussex: Harvester Press, 1976.

Wittgenstein introduces the possibility that mathematics has a context and asks questions about the things we take for granted; considers proof as something which is established in terms of "use and custom", and mathematics as "normative" in the sense of being an activity which is socially agreed. Brings out the linguistic roots of mathematics and claims that the laws of inference in mathematics have the same roots as any other laws of human society.

4028. Zilsel, Edgar. "The Sociological Roots of Science". *American Journal of Sociology* 47 (1942), 245–279. German translation, *Die sozialen Ursprünge der neuzeitlichen Wissenschaft.* Essays translated from the English and edited by W. Krohn. Frankfurt/M.: Suhrkamp, 1976, 49–65.

Argues for comparative and sociology analysis in the history of science, and finds the roots of the scientific revolution in the breakdown of the social barrier between intellectual and manual labor during the Renaissance. The German edition contains eight papers by Zilsel and a competent introduction by the editor on the sociological interpretation of modern science.

MATHEMATICS AND SOCIETY

4029. Fletcher, Colin R. "Refugee Mathematicians: A German Crisis and a British Response, 1933–1936". *Historia Mathematica* 13 (1986), 13–27.

The British response to the intellectual crisis precipitated by the Nazi accession to power in Germany.

4030. McArthur, Charles W. *Operations Analysis in the U.S. Army Eighth Air Force in World War II.* (History of Mathematics, No. 4.) Providence: American Mathematical Society, 1990, xxiv + 349 pp.

A study of the influence of World War II on one area of mathematics.

4031. Mehrtens, Herbert "Ludwig Bieberbach and 'Deutsche Mathematik.'," In Esther R. Phillips, ed. *Studies in the History of Mathematics.* Washington: Mathematical Association of America, 1987, 195–241.

A study of the leading mathematical journal in the Nazi era and its editor.

4032. Mehrtens, Herbert. "Mathematics in the Third Reich: Resistance, Adaptation, and Collaboration of a Scientific Discipline". In R. P. W. Visser, ed. *New Trends in the History of Science.* Amsterdam: Rodopi, 1989 151–166.

A study of the way in which mathematicians were affected by the Nazi regime.

4033. Rowe, David E. "'Jewish Mathematics' at Göttingen in the Era of Felix Klein". *Isis* 77 (1986), 422–449.

A study of the appropriation of Klein's legacy by the Nazis.

4034. Segal, Sanford L. "Mathematics and German Politics: The National Socialist Experience". *Historia Mathematica* 13 (1986), 118–135.

A general study of mathematics under the Nazis.

4035. Siegmund-Schultze, Reinhard. "Zur Sozialgeschichte der Mathematik an der Berliner Universität im Faschismus". *Zeitschrift für Geschichte der Naturwissenschaft, Technik, und Medizin* 26 (1) (1989), 49–68.

The National Socialist era in mathematics at the University of Berlin.

4036. Siegmund-Schultze, Reinhard. *Mathematische Berichterstattung in Hitlerdeutschland. Der Niedergang des Jahrbuchs über die Fortschritte der Mathematik.* (Studien zur Wissenschafts-, Sozial- und Bildungsgeschichte der Mathematik, 9.) Göttingen: Vandenhoeck & Ruprecht, 1993. x + 263 pp.

Mathematical reviewing in Hitler's Germany and the decline of the *Jahrbuch über die Fortschritte der Mathematik.* Reviewed by P. D. F. Ion, **MR** 95f:01041.

4037. Siegmund-Schultze, Reinhard *Mathematiker auf der Flucht vor Hitler: Quellen und Studien zur Emigration einer Wissenschaft.* Wiesbaden: Vieweg, 1998.

A comprehensive account of the flight from Nazi Germany of famous mathemticians such as Emmy Noether, John von Neumann, Richard Courant, and Hermann Weyl. Included are the reactions of German colleagues and experiences in new countries, mainly in the United States where most went to. Most were also Jewish and anti-Semitism continued to play a role in establishing their new lives.

PHILOSOPHY OF MATHEMATICS

The scope of philosophy of mathematics, so far as it is covered in the present bibliography, comprises: criticism and clarification of basic mathematical concepts, assumptions, and methods of proof; discussions of mathematical objects, truth, certainty, and objectivity; views concerning mathematical infinity; views about what the nature of mathematics is or should be (e.g., logicism and intuitionism), leading to systematic reconstructions of mathematics. The literature cited here includes works on the ancient philosophy of mathematics as represented by Plato and Aristotle, conceptual and methodological issues involved in the development of the calculus and extensions of the number system, the pre-Cantorian paradoxes of the infinite, Kant's philosophy of mathematics, and the philosophy of geometry. The period most extensively covered is the one extending from the 1870s to the 1920s—a time of remarkable advances by Frege, Dedekind, G. Cantor, Russell, Hilbert, and Brouwer, as well as of vigorous controversies concerning such matters as the antinomies of set theory and the relation between mathematics and logic. Some references also deal with main positions in the philosophy of mathematics which were formulated somewhat more recently.

4038. Wiener, P. P., ed. *Dictionary of the History of Ideas. Studies of Selected Pivotal Ideas*. New York: Charles Scribner's Sons, 1974. 4 vols. plus an index vol.

Articles by R. Blanché on "Axiomatization", by S. Bochner on "Continuity and Discontinuity in Nature and Knowledge" and on "Infinity", by R. L. Wilder on "Relativity of Standards of Mathematical Rigor". Bibliographies.

4039. Edwards, P., ed. *The Encyclopedia of Philosophy.* New York: Macmillan, 1967. 8 vols.

High quality articles, often quite substantial and always with bibliographies, on: "Zeno of Elea" by G. Vlastos, "Frege" by M. Dummett, "Russell, Logic and Mathematics" by A. N. Prior, "Hilbert" by P. Bernays, "Brouwer" by C. Parsons, "Antinomies" by J. van Heijenoort, "Continuum Problem" by R. Smullyan, "Foundations of Mathematics" by C. Parsons, "Geometry" by S. F. Barker, "Gödel's Theorem" by J. van Heijenoort, "Infinity in Mathematics and Logic" by J. Thomson, "Types" by Y. A. Bar-Hillel. The long article "Logic, History of," edited by A. N. Prior, has parts which are relevant to the philosophy of mathematics.

4040. *Encyklopädie Philosophie und Wissenschaftstheorie.* Edited by Mittelstraß, Jürgen. Stuttgart and Weimar: J. B. Metzler, 1980–1996, 4 vols., 835 pp., 1105 pp., 866 pp., 872 pp.

This large scale encyclopedia focuses on the philosophy of science and its history, but it has also entries on the whole ranges of logic and the philosophy of mathematics. Besides this it gives a comprehensive selection of biographical entries.

4041. Craig, Edward, ed. *Routledge Encyclopedia of Philosophy*. London and New York: Routledge, 1998. 10 vols.

The philosophy of mathematics is one of the focuses of this first choice encyclopedia. Among its 2054 entries are biographical articles, survey articles like "Mathematics, Foundations of" (M. Detlefsen) and topical articles like "Realism in the Philosophy of Mathematics" (P. A. Blanchette) or "Set Theory" (V. P. Burgess).

4042. *The Journal of Symbolic Logic*.

Volume 1 (1936) contains a bibliography by A. Church which was "intended to be a complete bibliography of symbolic logic for the period 1666–1935 inclusive." Many items belonging to the philosophy of mathematics are included. Additions, corrections, and indices to this bibliography are given in volume 3, and it is extended past 1935 by listings in each volume. A large number of entries are reviewed, but beginning with vol. 41, no. 2 (June 1976) mostly books are reviewed. A revised and expanded edition of this bibliography was published in a separate form: A. Church, *A Bibliography of Symbolic Logic (1666–1935). Revised and Expanded Edition. Reprinted from the Journal of Symbolic Logic*. Urbana, IL: Association for Symbolic Logic, 1984.

4043. *The Philosopher's Index. An International Index to Philosophical Periodicals*. Bowling Green, Ohio: Philosophical Documentation Center, Bowling Green State University, 1969–.

Coverage is from 1967 on. Abstracts are included in the 1969 and later editions. This index has been supplemented by *The Philosopher's Index. A Retrospective Index to U.S. Publications from 1940* (Bowling Green, Ohio: Philosophical Documentation Center, Bowling Green State University, 1978. 3 vols.). "Includes original philosophy books published in the United States between 1940 and 1976, and articles published in philosophy journals in the United States between 1940 and 1966."

4044. *Philosophia Mathematica* ser. III., 1 (1993)–.

The third series takes up an older project initiated by J. Fang (2nd ser. 1964–1992). Devoted to the "Philosophy of Mathematics, its learning, and its applications" (subtitle) it is published for the Canadian Society for History and Philosophy of Mathematics. The journal contains reviews and papers on the philosophy (and its history) of pure and applied mathematics including computing.

4045. Aspray, William and Philip Kitcher, eds. *History and Philosophy of Modern Mathematics*. Minneapolis: University of Minnesota, 1988, viii + 386 pp.

This volume is made up of fourteen papers which deal with the relations between historical, philosophical and methodological questions concerning the development of modern mathematics. Section I on the interrelations between logic and the foundations of mathematics contains Warren Goldfarb's "Poincaré against the Logicists", Michael Friedman's "Logical Truth and Analyticity in Carnap's 'Logical Syntax of Language'", and Gregory H. Moore's "The Emergence of First-Order Logic". Section II on reinterpretations gives papers by Harold Edwards (on Kronecker), Garrett Birkhoff and M. K. Bennett (on Felix Klein), Joseph W. Dauben (on A. Robinson), and Richard Askey on the relation between mathematicians and mathematical historians. Section III gives case studies, Lorraine J. Daston on probability theory, Howard Stein on "*Logos*, Logic, and *Logistikê*", giving philosophical remarks on 19th century transformation processes in mathematics which he characterizes as a second birth of the discipline, Michael J. Crowe on "Ten Misconceptions about Mathematics and its History", arguing against standard assertions on mathematical development, Felix E. Browder on the relation between mathematics and sciences and Philip Kitcher on mathematical naturalism. The volume ends with papers on the social context of modern mathematics by Judith V. Grabiner (on partisans and critics in artificial intelligence) and William Aspray on the emergence of Princeton towards a world center of mathematical research. The volume is accompanied by an "Opinionated Introduction" by the editors giving a survey of the state of art in the philosophy of mathematics and the metahistory of mathematics.

4046. Barker, S. F. "Logical Positivism and the Philosophy of Mathematics". In *The Legacy of Logical Positivism. Studies in the Philosophy of Science*. Edited by P. Achinstein and S. F. Barker. Baltimore: The Johns Hopkins Press, 1969, 229–257.

Gives an explanation of some basic positivist views relating to philosophy of mathematics and then attempts to account for an asymmetry in the positivist treatments of arithmetic and geometry: the formulas of arithmetic, but not those of geometry, are granted "a standard prevailing interpretation. . .under which they become analytic truths." See also A. Hausmann, "Non-Euclidean Geometry and Relative Consistency Proofs", in *Motion and Time, Space and Matter. Interrelations in the History of Philosophy and Science*, edited by P. K. Machamer and R. G. Turnbull (Columbus: Ohio State University Press, 1976), 418–435.

4047. Beaney, Michael. *Making Sense.* London: Duckworth, 1996, x + 358 pp.

The author considers G. Frege's distinction between "Sinn" and "Bedeutung", one of Frege's most important contributions to analytical philosophy, in his philosophies of mathematics and logic.

4048. Becker, Oskar. *Grundlagen der Mathematik in geschichtlicher Entwicklung.* Freiburg: Alber, 1954. 4th ed. Frankfurt a.M.: Suhrkamp, 1990, xii + 422 pp.

With historical thoroughness, the author concentrates on Greek, seventeenth-century, nineteenth-century, and twentieth-century foundations of mathematics. In particular, he discusses the first from the Eleatics to Proclus, the second in terms of the calculus, the third as it concerns the foundations of geometry, and the fourth vis-à-vis logicism, intuitionism, and formalism up to Lorenzen's work. The author publishes an extensive selections of key texts and combines them with his comments. See also item 880.

4049. Benacerraf, P. and H. Putnam, eds. *Philosophy of Mathematics, Selected Readings.* Englewood Cliffs, N.J.: Prentice-Hall, 1964, vii + 536 pp. Second ed. Cambridge: Cambridge University Press, 1983, viii + 600 pp.

Contains selections from Frege, Russell, Poincaré, Brouwer, and Hilbert. Also included are the 1931 symposium on the foundations of mathematics in which Carnap, Heyting, and von Neumann participated; two papers by Gödel, "Russell's Mathematical Logic" and "What Is Cantor's Continuum Problem?", which are classic expressions of mathematical realism; Bernays's "On Platonism in Mathematics," which is very rich in content, insightfully discussing much more than is indicated by the title. (For further papers by Bernays, see his *Abhandlungen zur Philosophie der Mathematik* [Darmstadt: Wissenschaftliche Buchgesellschaft, 1976]). "Hilbert's Program" by G. Kreisel remarks briefly on the development of Hilbert's views and the opposition between his approach and that of Brouwer, and then proceeds to a reconstruction of Hilbert's program. There are some very influential papers by W. V. Quine on ontology, conventional truth, and the analytic-synthetic distinction. C. G. Hempel's classic exposition of logicism is also reprinted here. The large section devoted to selections from and critical commentary on Wittgenstein's *Remarks on the Foundations of Mathematics*, edited by G. H. von Wright et al., translated by G. E. M. Anscombe (Cambridge, Mass.: MIT Press, 1967), is out of all proportion to its influence in the philosophy of mathematics. Bibliography.

4050. Bernays, Paul. *Abhandlungen zur Philosophie der Mathematik*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1976, x + 213 pp.

Paul Bernays was Hilbert's main collaborator in formulating the metamathematical program. These 14 essays give insights on his platonistic view of the foundations of mathematics which prevented him from sharing the reductionistic tendencies of strict formalism. On Bernays's philosophy of mathematics see also Gert H. Müller, ed. *Sets and Classes: On the Work by Paul Bernays*. Amsterdam: North-Holland, 1976.

4051. Bernays, P. "Hilberts Untersuchungen über die Grundlagen der Arithmetik". In D. Hilbert, *Gesammelte Abhandlungen*. Vol. 3. Berlin: Springer, 1935, (Second ed. Berlin, Heidelberg, New York: Springer, 1970), 196–216.

Describes the development of Hilbert's views on foundations, beginning with "Über den Zahlbegriff" (1900); also discusses papers bearing on Hilbert's program by Ackermann, von Neumann, and Gödel.

4052. Beth, Evert W. *Mathematical Thought. An Introduction to the Philosophy of Mathematics*. Dordrecht: Reidel, 1965, xii + 208 pp.

This book introduces several topics in the philosophy of mathematics: the criticism of mathematics as based on naive intuition, the foundations of arithmetic, symbolic logic and its relations with traditional logic, the struggle between intuitionism and formalism, the paradoxes, and the relation between significs and logic, the first being a specific Dutch theory on the signification of words. The book ends with some hints on later developments on the borderline between mathematics and logic.

4053. Beth, E. W. *The Foundations of Mathematics, A Study in the Philosophy of Science*. Amsterdam: North-Holland, 1959, xxvi + 741 pp. Rev. ed., second printing, 1968, xxviii + 741 pp.

Though the greater part of this large volume presents the fundamentals of many mathematical and logical theories of modern foundational studies, it begins with two chapters on ancient philosophy; for the author thinks "we must go back at least to Aristotle if we want to grasp the ultimate roots of the doctrinal divergences which have arisen from the results of modern research into the foundations of mathematics." The chapter on Aristotle's theory of science has sections on the theories of science of Nieuwentyt, a 17th-century critic of Leibniz's calculus, and of Kant. There are many brief historical and philosophical passages providing background for an exposition of technical results. Also included are chapters on logicism, Cantorism, intuitionism, and nominalism, as well as a very comprehensive chapter on the various mathematical paradoxes (seventeen are listed) and the most common methods of avoiding them.

4054. Black, M. *The Nature of Mathematics.* London: Kegan Paul, Trench, Trubner & Co; New York: Harcourt, Brace and Company, 1933. 5th impression, London: Routledge and Kegan Paul, 1965, xiv + 219 pp.

This is a philosopher's detailed critical analysis of logicism and, to a lesser extent, of formalism and intuitionism. The account of logicism includes not only Russell's and Whitehead's *Principia Mathematica*, but also the views of F. Ramsey, L. Chwistek, and L. Wittgenstein. The author emphasizes the need for mutual interaction among the three schools rather than simply within each of them.

4055. Bolzano, B. *Paradoxien des Unendlichen.* Edited by F. Přihonský. Leipzig, 1851, xi + 151 pp. Paperback edition (second ed.) edited by B. van Rootselaar, Hamburg: Meiner, 1975, xxvi + x + 156 pp. A critical edition is going to be published in *Bernard Bolzano-Gesamtausgabe.* Stuttgart-Bad Cannstatt: Friedrich Frommann Verlag (Günther Holzboog), ser. II A, vol 11.English translation with historical introduction by D. Steele: *Paradoxes of the Infinite.* London: Routledge and Kegan Paul, 1950.

In preparation for a discussion of the paradoxes or *apparent* contradictions, Bolzano tries to give precise explanations or definitions of such concepts as *set, sum, quantity, series, finite*, and *infinite*. An infinite set is defined as one which is not finite, but his definition of *finite* is not satisfactory. He proceeds to criticize definitions of infinite given by others, to refute those denying the possibility of anything infinite, and to offer a proof of the existence of infinite sets. The most interesting of the paradoxes discussed is the fact that an infinite set is reflexive. He resolves this by denying that one-one correspondence is the criterion of quantitative equality for infinite sets, but is then left with an unexplained concept, "equality in multiplicity." Bolzano also discusses the fundamentals of differential calculus and the concepts of a continuum and of dimension.

4056. Boyer, Carl B. *History of the Calculus and Its Conceptual Development.* New York: Dover, 1959.

This is an unaltered reprint of *The Concepts of the Calculus, a Critical and Historical Discussion of the Derivative and the Integral.* New York: Columbia University Press, 1939.

An account is given of ancient and medieval thought concerning number, continuity, indivisibles and infinitesimals, the infinite, and motion; over half the book is devoted to the conceptual developments preceding Newton and Leibniz. There is also an account of the various criticisms of the unclear Newtonian and Leibnizian "foundations" by Nieuwentyt, Berkeley, and the French Academy of Sciences, as well as of 18th-century attempts to improve the conceptual foundations of the calculus. Both favorable aspects and deficiencies are indicated; there is attention to the influences of philosophical, geometrical, mechanical, and formalistic ideas. The last chapter contains a description of the aspects of the full rigorous formulation contributed by Bolzano, Cauchy, Weierstrass, Dedekind, and G. Cantor. See also F. Cajori, *A History of the Conceptions of Limits and Fluxions in Great Britain from Newton to Woodhouse* (item 2612 above)—nearly a whole volume, centering on the criticisms in Berkeley's *Analyst*, of quotations of explanations and criticisms relating to the concepts of fluxions and limits. See also item 2078.

4057. Brittan, G. G., Jr. *Kant's Theory of Science.* Princeton: Princeton University Press, 1978, xii + 215 pp.

Chapter 2, "Kant's Philosophy of Mathematics," discusses the main recent interpretations of reconstructions of the meaning and justification of Kant's thesis that mathematical propositions are synthetic a priori truths; references are given to the relevant works of Beth, Hintikka, and Parsons, in which many further references are to be found. In Chapter 3, "Geometry, Euclidean and Non-Euclidean," an attempt is made to separate Kant's arguments for the theses that Euclidean geometry is synthetic and that it is a priori. Views in opposition to the first thesis are evaluated.

4058. Brouwer, L. E. J. *Collected Works.* Vol. 1. *Philosophy and Foundations of Mathematics.* Edited by A. Heyting. Amsterdam: North-Holland, 1975, xvi + 628 pp.

Contains a translation of Brouwer's 1907 thesis, "On the Foundations of Mathematics"—from the historical point of view, the most interesting of his philosophical writings. Here he advances his view that all legitimate mathematics is constructed from a basic intuition: "a unity of continuity and discreteness, a possibility of thinking together several entities, connected by a 'between,' which is never exhausted by the insertion of new entities," "the intuition of many-oneness." It is maintained that mathematical construction is separate from language and logical reasoning. There are observations on the antinomies and criticisms of Dedekind's system of arithmetic, the logistic systems of Russell and Peano, G. Cantor's theory of the transfinite, and Hilbert's 1904 paper. The thesis does not reject the law of excluded middle; doubts are first expressed about it in a 1908 paper appearing here in an English translation, "The Unreliability of the Logical Principles." Numerous other papers on philosophy and intuitionistic mathematics are also included in this volume. On Brouwer's life and work see Walter van Stigt, *Brouwer's Intuitionism* (Amsterdam: North-Holland, 1990, xxvi + 530 pp.), and Miriam Franchella, *L. E. J. Brouwer pensatore eterodosso* (Milano: Guerini, 1994, 238 pp.). For a complete bibliography including articles in newspapers and magazines see D. van Dalen, *A Bibliography of L. E. J. Brouwer* (Utrecht: Department of Philosophy, 1997, 42 pp.).

4059. Brunschvicg, L. *Les étapes de la philosophie mathématique.* Paris: Alcan, 1912. Recent edition: Paris: Blanchard, 1972, xi + 591 pp.

A distinctively French philosophical analysis of the entire history of European mathematics from the Pythagoreans to the First World War. Although the author mentions logicism, he treats the modern period briefly. By contrast, he dwells on Descartes, Leibniz, Kant, and Comte.

4060. Bunn, R. "Quantitative Relations Between Infinite Sets". *Annals of Science* 34 (1977), 177–191.

Examines some medieval arguments concerning the once wide-spread view that one infinite cannot be greater than another. The different treatments by Galileo, Leibniz, and Bolzano of the paradox of the infinite, involving the reflexivity of infinite sets, are analyzed and the logical error common to their arguments is pointed out. The relation of G. Cantor's theory to this matter is also discussed. See also item 3142.

4061. Cantor, Georg. *Gesammelte Abhandlungen mathematischen und philosophischen Inhalts.* Edited by E. Zermelo. Berlin: J. Springer, 1932, 486 pp. Reprinted Hildesheim: Olms, 1962; Berlin: Springer-Verlag, 1990.

Contains G. Cantor's attempts to defend his theory of the transfinite from traditional objections to the infinite, many of which go back to Aristotle, and his opposition to the restrictions on mathematical concepts and theories backed by his contemporary critic, L. Kronecker. Also included are letters to Dedekind in which are stated certain of the antinomies which Cantor was the first to discover, and his means of reformulating the foundations of set theory in light of these antinomies. Cantor's correspondence has been edited (in a selection with a survey of all other letters) by H. Meschkowski and W. Nilson. See also I. Grattan-Guinness, "The Rediscovery of the Cantor-Dedekind Correspondence", *Jahresbericht der Deutschen Mathematiker-Vereinigung* 76 (1974), 104–139, and "The Correspondence Between Georg Cantor and Philip Jourdain", *Jahresbericht der Deutschen Mathematiker-Vereinigung* 73 (1971), 112–130. The 1990 reprint also contains a list of works by Cantor not included in the 1932 *Gesammelte Abhandlungen*, as well as publications containing letters and previously unpublished materials by Cantor.

4062. Cavaillès, J. *Philosophie mathématique.* Paris: Hermann, 1962, 274 pp.

This volume consists of three parts: a historical study of set theory and its philosophical presuppositions from G. Cantor to Zermelo; a French translation of the Cantor-Dedekind correspondence; and an essay on the researches of Gentzen and Gödel vis-à-vis consistency. See also the author's *Méthode axiomatique et formalisme* (Paris: Hermann, 1938), in three volumes. Here three essays are included: "Le problème du fondement des mathématiques", "Axiomatique et système formel", and

"La non-contradiction de l'arithmétique". These books, together with further papers on the philosophy of mathematics and the philosophy of science and biographical material, are collected in Cavaillès's *Oeuvres complètes de philosophie des sciences*. Edited by B. Huisman, Paris: Hermann, 1994. On Cavaillès's philosophy of mathematics see Hourya Sinaceur, *Jean Cavaillès: Philosophie mathématique* (Paris: Presses Universitaires de France, 1994, 128 pp.). See also item 3143.

4063. Chihara, C. S. *Ontology and the Vicious-Circle Principle*. London, Ithaca, N.Y.: Cornell University Press, 1973, xv + 257 pp.

Not intended as a history, though it deals with the views of Russell, Gödel, Quine, and Poincaré. The chapter, "Poincaré's Philosophy of Mathematics," is the most valuable as history. There the author stresses "the difficulties involved in reconstructing a coherent view of mathematics from the many paradoxical claims [Poincaré] made"; his treatment, however, is most sympathetic. The chapter on Russell is also of some use in the difficult project of trying to understand his thought on the solution of the antinomies, and related matters.

4064. Chihara, Charles S. *Constructibility and Mathematical Existence*. Oxford: Clarendon Press, 1990, xvi + 282 pp.

After a discussion of Quine's and Gödel's platonism and Heyting's intuitionism as ways to deal with the problem of existence in mathematics, the author proposes what he calls "constructibility theory" as an alternative, testing it by applying it to number theory and analysis. The second part gives a critical discussion of recent concepts in the philosophy of mathematics such as mathematical structuralism (S. Shapiro, M. Resnik), H. Field's nominalistic instrumentalism, J. Burgess's moderate realism, P. Maddy's realism and P. Kitcher's non-platonistic epistemological approach.

4065. Church, Alonzo. *Introduction to Mathematical Logic*. Princeton, N.J.: Princeton University Press, 1956, x + 378 pp. 10th printing, 1996.

In addition to historical notes (pp. 155–166, 288–294), this volume contains a lengthy quasi-historical introduction to the notions of proof, syntax, semantics, and the logistic method, by the mathematician who successfully established the study of mathematical logic in the United States. See also item 3145.

4066. Corry, Leo. *Modern Algebra and the Rise of Mathematical Structures*. Basel, Boston, Berlin: Birkhäuser, 1996, xvi + 460 pp.

This book provides a historical approach to elucidate the genesis and development of the structural approach to mathematics. In part I the author describes the development of ideal theory from R. Dedekind to E. Noether. Part II treats the approaches of O. Ore, N. Bourbaki, and of category theory as further developments of the concept of mathematical structure.

4067. Curry, H. B. *Outlines of a Formalist Philosophy of Mathematics.* Amsterdam: North-Holland, 1951, vii + 75 pp., 3rd printing, 1970.

Although not a history, this book attempts to present a philosophy of mathematics from the standpoint of a working mathematician. To do so, he treats the notion of "formal system" in depth. He argues for a formalist definition of mathematics as the science of formal systems.

4068. Czermak, Johannes, ed. *Philosophy of Mathematics: Proceedings of the 15th International Wittgenstein-Symposium. 16th to 23rd August 1992, Kirchberg am Wechsel (Austria).* Vol. 1. Vienna: Hölder-Pichler-Tempsky, 1993, 445 pp.

This volume with thirty-six papers covers a large variety of topics. They include the history of mathematical ideas, a discussion of M. Dummett's book *Frege: Philosophy of Mathematics* (see item 4075), intuitionism and constructive mathematics, Hilbert's program and Gödel's theorems, logicism, mathematics in its relation to modality and knowability, some specific philosophies of mathematics, and miscellaneous topics.

4069. Dales, H. G. and G. Oliveri, eds. *Truth in Mathematics.* Oxford: Clarendon Press, 1998, xvi + 376 pp.

The eighteen papers of this collection deal with the problem of truth in mathematics approaching it from different perspectives such as verificationism, constructivism, formalism, naturalism and realism.

4070. Dauben, Joseph Warren. *Georg Cantor, His Mathematics and Philosophy of the Infinite.* Cambridge, Mass.: Harvard University Press, 1979, 361 pp.. Paperback reprint, Princeton, N.J.: Princeton University Press, 1990.

Chapters 6, 10, 11. Along with much else relating to Cantor's philosophy, an account is given of Cantor's answers to traditional criticisms of the actual infinite by philosophers and theologians; his view that though transfinite numbers have a sort of metaphysical reality, only their consistent and distinct conception is necessary for mathematical admissibility; Frege's critique of Cantor's use of abstraction and his definitions of such concepts as *power* of a set and *finite* set; Cantor's discovery, use, and probable interpretation of the antinomies. Various post-Cantorian developments concerning the antinomies and axiomatics are also described; in particular, there is a detailed relation of the opposition by Borel and Lebesgue to Zermelo's proof of the well-ordering theorem and its defense by Hadamard. There are copious references to Cantor's correspondence as well as to his publications, and a large bibliography. See also item 3150 and 2627.

4071. Davis, Martin, ed. *The Undecidable: Basic Papers on Undecidable Propositions, Unsolvable Problems and Computable Functions.* New York, 1965, 440 pp.

This selection compiles classical papers on the topics indicated in the subtitle by K. Gödel, A. Church, A. M. Turing, J. B. Rosser, S. C. Kleene, and E. L. Post, among them Post's long unpublished paper "Absolutely Unsolvable Problems and Relatively Undecidable Propositions—Account of an Anticipation."

4072. Davis, Philip J., Reuben Hersh, and Elena Anne Marchisotto. *The Mathematical Experience. Study Edition.* Boston, Basel, and Berlin: Birkhäuser Verlag, 1995, xxiv + 487 pp.

This book, originally published in 1991, aims at a non-professional audience, attempting to convey the fascination of mathematics. The authors are, however, very sensible towards philosophical issues, like types of mathematical experience, mathematical certainty, foundational problems, and types of mathematical reality.

4073. Detlefsen, Michael. *Hilbert's Program. An Essay on Mathematical Instrumentalism.* Dordrecht et al.: Reidel, 1986, xiv + 186 pp.

Detlefsen gives an epistemological interpretation of Hilbert's special sort of instrumentalism and its applications to a selection of foundational problems in mathematics.

4074. Dugac, Pierre. *Richard Dedekind et les fondaments des mathématiques (avec de nombreux textes inédits).* Paris: Vrin, 1976, 334 pp.

On Dedekind's philosophy of mathematics. See also D. A. Gillies. *Frege, Dedekind, and Peano on the Foundations of Arithmetic*, (Assen: van Gorcum, 1982, ix, 103 pp.).

4075. Dummett, Michael. *Frege: Philosophy of Mathematics.* Cambridge, Mass.: Harvard University Press, 1991, xiii + 331 pp. Second impression, London: Duckworth, 1995.

Dummett gives an interpretation of Frege's *Grundlagen der Arithmetik* (1884) and of his *Grundgesetze der Arithmetik* (1893/1903) focusing on the role of the context principle in Frege's philosophy of mathematics, according to which a word has meaning only in the context of a complete sentence.

4076. Echeverría, Javier, Andoni Ibarra, and Thomas Mormann, eds. *The Space of Mathematics. Philosophical, Epistemological, and Historical Explorations. Revised Papers from a Symposium on Structures in Mathematical Theories, Donostia/San Sebastian, Basque Country,* *Spain, September 1990.* Berlin: Walter de Gruyter, 1992, xvi + 422 pp.

Most of the papers concern the empirical aspects of mathematical theories, above all the question whether mathematics can be reconstructed like empirical theories. The conference proceedings containing 70 short papers have been edited by Amparo Díez, Javier Echeverría, and A. Ibarra. *Structures in Mathematical Theories. Reports of the San Sebastian International Symposium September 25–29, 1990.* (Bilbao: Servicio Editorial Universidad del Pais Vasco, 1990, 492 pp.).

4077. Engfer, Hans-Jürgen. *Philosophie der Analysis. Studien zur Entwicklung philosophischer Analysiskonzeptionen unter dem Einfluß mathematischer Methodenmodelle im 17. und frühen 18. Jahrhundert.* Stuttgart-Bad Cannstatt: Frommann-Holzboog, 1982, 293 pp.

This book gives a survey on rationalistic attempts to utilize the synthetic "mathematical method" for philosophy and the opposition by Kant and other philosophers who maintained that the analytic method is the philosophical method. Several types of mathematical methods are presented, in particular the conceptions of Descartes, Leibniz, and Christian Wolff.

4078. Ewald, William, ed. *From Kant to Hilbert: A Source Book in the Foundations of Mathematics.* Oxford: Clarendon Press, 1996, 2 vols., xviii + 1340 pp.

Despite its title this collection covers the period between George Berkeley and Bourbaki. In 28 sections it gives a large variety of historical key texts for the philosophy of mathematics, in sum 86 selections of which 56 are translations. Some of them are published for the first time in English language, such as Bolzano's "Contributions to a better-grounded presentation of mathematics" (1810), or G. Cantor's "Foundations of a general theory of manifolds" (1883). All selections are accompanied by useful introductions by the editor.

4079. Fang, Joong. *Bourbaki: Towards a Philosophy of Modern Mathematics.* Hauppauge and New York: Paideia, 1970, 144 pp.

The author focuses on a view on the philosophy of mathematics which is not restricted to foundations or the relation between logic and mathematics. Besides the book on Bourbaki, he also published a survey of David Hilbert's creative years: *Hilbert. Towards a Philosophy of Modern Mathematics II*, (Hauppauge: Paideia, 1970, 205 pp.).

4080. Ferreirós, José. "Traditional Logic and the Early History of Sets, 1854–1908". *Archive for History of Exact Sciences* 50 (1996), 5–71.

The emergence of set theory is connected to 19th century logic in Germany. The doctrines concerning concepts and their formation in traditional logic are presented and related to Riemann's manifolds, Dedekind's logical theory of systems, the problem of infinity and the impact of the antinomies.

4081. Finsler, Paul. *Aufsätze zur Mengenlehre.* Edited by Georg Unger, Darmstadt: Wissenschaftliche Buchgesellschaft, 1975, xvi + 242 pp.

This selection contains 18 texts of Finsler's attempts to give a consistent foundation of mathematics using a non-formalized axiomatics of set theory, based on what he calls an "absolute logic". On Finsler's set theory see Herbert Breger, "A Restoration That Failed: Paul Finsler's Theory of Sets", in D. Gillies, ed., *Revolutions in Mathematics*, (Oxford: Clarendon Press, 1992), 249–264. (See item 4093).

4082. Folina, Janet M. *Poincaré and the Philosophy of Mathematics.* Houndsmills and London: Macmillan, 1992, xvii + 202 pp.

The author gives a description of the full range of Poincaré's philosophy of mathematics, such as his apriorism founded on Kant's critical philosophy, his attacks on logicism, his positions towards set theory, predicativity and meaning.

4083. Fraenkel, A. *Einleitung in die Mengenlehre.* Berlin: J. Springer, 1919. 3rd ed., revised and enlarged, 1928, vi + 156 pp. Reprinted New York: Dover, 1946, Walluf: Sändig, 1972.

Not just a text on set theory; a work of considerable historical interest, long a principal reference on set theory and foundations of mathematics. Attention is given to conceptual matters throughout, and the last two chapters contain extensive discussions of the antinomies, intuitionism, impredicative definitions, logicism, the axioms of set theory and the axiomatic method in general, and Hilbert's program. A scholarly work giving a large number of references. Substantial bibliography. Fraenkel's own contributions to the development of abstract set theory are reflected in a volume dedicated to him on the occasion of his seventieth birthday: *Essays on the Foundations of Mathematics*, edited by Y. Bar-Hillel et al. (Amsterdam: North-Holland, 1962). It contains 23 papers organized in the following four parts: "Axiomatic Set Theory", "Mathematical Logic", "Foundations of Arithmetic and Analysis", "Philosophy of Logic and Mathematics."

4084. Fraenkel, A. *Abstract Set Theory.* Amsterdam: North-Holland, 1953, xii + 479 pp.. 4th rev. ed., 1976; second printing, 1984.

Has a bibliography section of 137 pages containing many references belonging to the philosophy of mathematics. More recent editions contain much shorter bibliographies.

4085. Fraenkel, A., Y. A. Bar-Hillel, and A. Levy, with D. van Dalen. *The Foundations of Set Theory.* Second rev. ed., Amsterdam: North-Holland, 1973, x + 404 pp.

Not on the whole a historical treatment of the foundations of set theory, but contains a number of valuable historical sections and references. In particular, there are historical introductions on the antinomies, on intuitionism, and on Hilbert's program. There is also a section on attitudes taken to the axiom of choice and a section on the logistic thesis. The last section of the book is a survey of some of the main views on the question of the reality of mathematical objects as these were formulated in the 1940s and 1950s. The 1958 edition by Fraenkel and Bar-Hillel contains a more extensive bibliography of older works and a large bibliography on the antinomies. See also item 3154.

4086. Frege, Gottlob. *Grundgesetze der Arithmetik, begriffsschriftlich abgeleitet.* Vol. 1, 1893, xxxii + 254 pp.; vol. 2, 1903, xvi + 266 pp. Reprinted Hildesheim: Olms, 1962, 1966. Vol. 1 is partially translated by Montgomery Furth under the title *The Basic Laws of Arithmetic*, Berkeley: University of California Press, 1964. Reprinted, 1982 Selections from vol. 2 are translated by P. Geach and M. Black in *Translations from the Philosophical Writings of Gottlob Frege.* 3rd ed. Oxford: Blackwell, 1960. Enlarged with translations of further parts in M. Beaney, ed. *The Frege Reader.* Oxford: Blackwell, 1997 (see item 4089).

This is Frege's main work in logic and foundations of mathematics. The introduction to Volume 1 contains an exposition of his objective point of view mainly by contrasting it with that of the idealistic logicians of his time. It seems safe to say that nobody so vigorously opposed any intrusion of psychology into mathematics as Frege. The amount of critical examination of others is a prominent feature of Frege's writings. About one-third (sections 55–164) of the second volume is devoted to a discussion of matters relating to the foundations of the theory of real numbers; most of this is remarkably detailed criticism of the methods of G. Cantor, Dedekind, Weierstrass, Hankel, and the formalists of the time represented mainly by Heine and Thomae. (Sections not translated by Geach and Black are: 55, 68–85, on Cantor; 138, 145, 148–164, on Weierstrass and on Frege's way of conceiving the real numbers. The pages 55–67, 138–147, and the appendix are translated in Beaney's edition [item 4089].) Frege's criticism of formalism had the approval of Hilbert and is apparently still topical: in a paper commenting on "popular discussions of foundations," G. Kreisel says it is "quite wrong not to use the penetrating and detailed analysis by the pioneers of modern logic [such as Frege]."

4087. Frege, Gottlob. *Grundlagen der Arithmetik: Eine logisch mathematische Untersuchung über den Begriff der Zahl.* Breslau: Koebner, 1884, xi + 119 pp. A critical edition was edited as *Centenarausgabe* by

Christian Thiel, Hamburg: Felix Meiner Verlag, 1986, lxiv + 187 pp. English translation by J. L. Austin. *The Foundations of Arithmetic: A Logico-Mathematical Enquiry into the Concept of Number*. Second ed. Oxford: Blackwell, 1953. Reprinted Evanston: Northwestern University Press, 1968,1980.

This great classic critically examines previous views on the basic concepts of arithmetic and addresses the question of whether the propositions of arithmetic are synthetic a priori as Kant maintained, or analytic in the sense of being derivable by logical principles from definitions. Frege tried to show the latter by defining the concept "finite number" and deriving the principle of mathematical induction, "which is ordinarily held to be peculiar to mathematics, but is really based on the universal principles of logic." His definitions were formulated as they were, not because they were most "natural," but because they could serve as the foundation of proofs. While nobody was more insistent on the necessity of proving existence and uniqueness theorems justifying definitions than Frege, these justifying demonstrations have to come from logic if the theorems derived from the definitions are to be analytic. But principles from which existential propositions follow are prime candidates for the designation "peculiar to mathematics" or even "synthetic," rather than "universal principles of inference." The *Centenarausgabe* contains besides the editor's historical introduction complementary texts such as the reviews by R. Hoppe, G. Cantor (including E. Zermelo's commentary and Frege's rejoinder), E. Eucken, K. Laßwitz, and the commentaries by E. Schröder, E. Husserl and H. Scholz. See also Charles Parsons, "Frege's Theory of Number" in *Philosophy in America*, edited by M. Black (Ithaca: Cornell University Press,1965), 180–203.

4088. Frege, Gottlob. *Philosophical and Mathematical Correspondence*. Chicago: University of Chicago Press, 1980, xviii + 218 pp.

A translation of the German edition, this book contains correspondence on the foundations of mathematics (especially geometry and logic) by Frege and Hilbert, Husserl, Peano, Russell, and G. Vailati, among others. See item 344—Frege's *Nachgelassene Schriften*, where posthumous writings appear in vol. 1; correspondence in vol. 2.

4089. Frege, Gottlob. *The Frege Reader*. Edited by Michael Beaney, Oxford: Blackwell, 1997, xvi + 409 pp.

This reader brings together all of Frege's seminal papers, substantial parts of all three of his books, and additional selections from his posthumous writings and correspondence. Some of the pieces are provided in new or revised translations.

4090. Friedman, Michael. *Kant and the Exact Sciences.* Cambridge, Mass., and London: Harvard University Press, 1992, xx + 357 pp.

This book gives a detailed discussion of Kant's developing positions in the philosophies of mathematics and science, as they can be obtained especially from the writings of his critical period and from his *Opus postumum.* Kant's achievement is seen within the scientific context of his time, because it "consists precisely in the depth and acuity of his insight into the state of the mathematical exact sciences as he found them" (p. xii).

4091. Gauthier, Yvon. *Fondements des mathématiques: Introduction à une philosophie constructiviste.* Montreal: Université de Montréal, 1976, 460 pp.

The author—a philosopher well versed in recent technical results from the foundations of mathematics—analyzes such results à propos of set theory, intuitionism, and category theory. In conclusion, he uses this analysis to discuss what mathematical logic has contributed to the philosophy of mathematics.

4092. Gentzen, Gerhard. "Die gegenwärtige Lage in der mathematischen Grundlagenforschung". *Forschungen zur Logik und zur Grundlegung der exakten Wissenschaften*, n.s. no. 4 (1938), 5–18. Reprinted together with the paper "Neue Fassung des Widerspruchsfreiheitsbeweises für die reine Zahlentheorie", Darmstadt: Wissenschaftliche Buchgesellschaft, 1969. English translation: "The Present State of Research into the Foundations of Mathematics". In *The Collected Papers of Gerhard Gentzen.* Edited by M. E. Szabo, Amsterdam: North-Holland, 1969, 234–251.

This is an eyewitness report on the state of foundational studies in the 1930s. Gentzen discusses different points of views concerning the antinomies and the concept of infinity (formalism, intuitionism, finitism), the axiomatic method, metamathematics (consistency proofs, decision problem), the theorems of Gödel and Skolem and the concept of the continuum. It is noteworthy that this paper also appeared in the National Socialist journal *Deutsche Mathematik* 3 (1939), 255–268, where it played a significant role in supporting Heinrich Scholz in his struggle against the "German mathematician" Max Steck who had offended the foundational studies in the Hilbert school as too abstract and therefore being "undeutsch". See Max Steck, *Das Hauptproblem der Mathematik*, second edition, (Berlin: Lüttke, 1943, xix + 252 pp.).

4093. Gillies, Donald, ed. *Revolutions in Mathematics.* Oxford: Oxford University Press, 1992, viii + 353 pp.

The papers in this volume are devoted to the question whether Thomas S. Kuhn's criteria for revolutionary change in science can be applied for mathematical development. The volume starts with three classical texts on this question, Michael Crowe's "Ten 'Laws' Concerning Patterns of Change in the History of Mathematics" (1975), Herbert Mehrtens' rejoinder (1976) and Joseph Dauben's proposal of "conceptual revolutions" (1984). Beside meta-historiographical papers by C. Dunmore and M. Crowe it contains case studies by P. Mancosu on Descartes's *Géométrie*, E. Grosholz on Leibniz's mathematics, G. Giurello on the history of the calculus, Y. Zheng on Non-Euclidean geometries, L. Boi on 19th century space conceptions, J. Gray on the 19th century revolution in mathematical ontology, H. Breger on P. Finsler's set theory and D. Gillies on a Fregean revolution in logic.

4094. Gödel, Kurt. *Collected Works*. Edited by Solomon Feferman, et al., New York: Oxford University Press, Oxford: Clarendon Press, 1986–1995, 3 vols., xi + 474 pp.; xvi + 407 pp.; xviii + 532 pp.

A fourth volume with correspondence is planned. The *Collected Works* combine critical editions of Gödel's works, unpublished papers and lectures with translations and comments. See also his *Unpublished Philosophical Essays*, edited by Francisco A. Rodríguez-Consuegra, (Basel, Boston and Berlin: Birkäuser Verlag, 1995, 235 pp.). This edition contains Gödel's paper "Some Basic Theorems on the Foundations of Mathematics and their Philosophical Implications" (1951) and two versions of his "Is Mathematics Syntax of Language?" (1953–54, 1955–56). It is accompanied by a comprehensive introduction by the editor "Kurt Gödel and the Philosophy of Mathematics" (pp. 17–106) focusing on Gödel's realism based on an analogy between mathematics and physics. For a discussion of Gödel's incompleteness theorems in their broader context see S. G. Shanker, ed. *Gödel's Theorem in Focus*, (London, New York and Sydney: Croom Helm, 1988, ix + 261 pp.). Authors include J. W. Dawson, S. C. Kleene, S. Feferman, M. D. Resnik, M. Detlefsen, and S. G. Shanker An English translation of Gödel's classical "On Formally Undecidable Propositions of *Principia Mathematica* and Related Systems I" (1931) is provided.

4095. Gonseth, Ferdinand. *Les fondaments des mathématiques*. Paris: Blanchard, 1926.

Gonseth proposed an "idoneism" standing for a schematized correspondence between language sign and, in the case of geometry, constructed objects. See Gerhard Heinzmann, *Schematisierte Strukturen. Eine Untersuchung über den "Idoneïsmus" Ferdinand Gonseth's auf dem Hintergrund eines konstruktivistischen Ansatzes*, (Berne and Stuttgart: Haupt, 1982, 185 pp.). On Gonseth's biography see Eric Emery, *Ferdinand Gonseth. Pour une philosophie dialectique ouverte à l'expérience*, (Lausanne: L'Age d'Homme, 1985, 323 pp.). Gonseth's philosophy of mathematics is treated in the second and third part (pp. 45–115). The volume closes with a selection of statements by Gonseth reconsidering his philosophy.

4096. Gonzalez, Wenceslao J. "Intuitionistic Mathematics and Wittgenstein". *History and Philosophy of Logic* 12 (1991), 167–183.

4097. Grattan-Guinness, Ivor. *Dear Russell–Dear Jourdain: A Commentary on Russell's Logic, Based on His Correspondence with Philip Jourdain*. New York: Columbia University Press; London: Duckworth, 1977, vi + 234 pp.

Russell's correspondence with Jourdain reveals much regarding his struggle from 1904 to 1907 to find a solution to the antinomies and formulate a satisfactory system of basic concepts and assumptions for the logical development of mathematics. There is material on Russell's thought about the existence or, better, the nonexistence of classes and about the axioms of choice and infinity. The author provides background information and some criticism, as well as a translation of Russell's 1911 "Sur les axiomes de l'infini et du transfini." Large bibliography. See also items 3157, 3148, 4097.

4098. Grattan-Guinness, Ivor, ed. *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. London and New York: Routledge, 1994, xiv + 1806 pp. 2 vols.

Although philosophical aspects can be found throughout this work, there is a special part (part 5, vol. 1, pp. 595–707) devoted to "Logic, set theories, and the foundation of mathematics". It contains 12 sections, among them contributions by Stewart Shapiro on "Metamathematics and Computability", Michael Detlefsen on "Constructivism", Nicolas D. Goodman on "Some Current Positions in the Philosophy of Mathematics", and Peter Schreiber on "Algorithms and Algorithmic Thinking through the Ages".

4099. Grelling, Kurt. "Philosophy of the Exact Sciences". In *Philosophy Today. Essays on Recent Developments in the Field of Philosophy*. Edited by E. L. Schaub. La Salle, Ill.: Open Court, 1928, 393–415. Reprinted Freeport, N.Y.: Books for Libraries, 1968.

This is a contemporary survey on the state of research in the philosophy of mathematics and the philosophy of science from the perspective of the Berlin variant of neo-positivistic philosophy. Main topics are the different positions in the "*Grundlagenstreit*", the axiomatization of set theory and the philosophy of theoretical physics as represented, e.g., by the work of Hans Reichenbach, the head of the Berlin Society for Scientific Philosophy.

4100. Haaparanta, Leila, ed. *Mind, Meaning and Mathematics. Essays on the Philosophical Views of Husserl and Frege*. Dordrecht, Boston, London: Kluwer 1994, xii + 278 pp.

The papers in this volume are devoted to the relation between Edmund Husserl and Gottlob Frege. Two papers are of particular interest for the philosophy of mathematics, Richard Tieszen's comparison of

Frege's and Husserl's positions concerning the philosophy of arithmetic (pp. 85–112), and Claire Ortiz Hill's account of their discussion on Leibniz's principle of the substitution of identicals (pp. 113–140), a principle which was sometimes called "the mathematical inference."

4101. Hahn, Hans. *Empiricism, Logic, and Mathematics: Philosophical Papers*. Edited by B. F. McGuinness. Dordrecht: Reidel, 1980, xix + 139 pp.

Hahn is the most profiled philosopher of mathematics of the Vienna Circle. The German versions are reprinted in Hans Hahn, *Collected Works*, Vol. 3, edited by L. Schmetterer and K. Sigmund (Vienna and New York: Springer, 1997), 403–562. These reprints are accompanied by a critical commentary by Christian Thiel (385–400). A vivid impression of the philosophy of mathematics as discussed in the Logical Empiricism can be obtained from a discussion on the foundations of mathematics which took place on the occasion of the Second Congress for the Philosophy of Exact Sciences at Königsberg. Besides Hahn R. Carnap, K. Gödel, A. Heyting, K. Reidemeister, H. Scholz, and J. von Neumann took part. The results were published under the title "Diskussion zur Grundlegung der Mathematik" in *Erkenntnis* 2 (1931), 135–151, translated by John W. Dawson in John W. Dawson, "Discussion on the Foundations of Mathematics", *History and Philosophy of Logic* 5 (1984), 111–129.

4102. Hallett, Michael. *Cantorian Set Theory and Limitation of Size*. Oxford: Clarendon Press, 1984, xxii + 343 pp.

The problems of the infinite in set theory from its Cantorian origins to axiomatic set theory (Fraenkel, Zermelo, von Neumann) are discussed focusing on the limitation of size argument which should help to avoid overly large sets which were seen as one of the reasons for the paradoxes.

4103. Hankins, Thomas L. "Algebra as Pure Time: William Rowan Hamilton and the Foundations of Algebra". In *Motion and Time. Space and Matter. Interrelations in the History of Philosophy and Science*. Edited by P. K. Machamer and R. G. Turnbull. Columbus: Ohio State University Press, 1976, 327–359.

Using correspondence and manuscripts, the author gives an account of the various influences on and the development of Hamilton's thinking on foundations and its relation to Kant. For a reconstruction of Hamilton's efforts, an analysis of defects, and a discussion of the lack of influence of his ideas, see J. Mathews, "William Rowan Hamilton's Paper of 1837 on the Arithmetization of Analysis", items 2326 and 2747.

4104. Heath, T. *Mathematics in Aristotle*. Oxford: Oxford University Press, 1949, xiv + 291 pp. Last reprint Bristol: Thoemmes Press, 1996.

A translation, with commentary, of those parts of the various works of Aristotle which in any way concern mathematics. Besides this classic see also H. G. Apostle *Aristotle's Philosophy of Mathematics* (Chicago: University of Chicago Press, 1952, 3rd impression, 1965); and

John J. Cleary *Aristotle and Mathematics: Aporetic Method in Cosmology and Metaphysics* (Leiden: Brill, 1995, xxxvi + 558 pp.). Andreas Graeser edited a collection of 12 papers in English, German and French on *Mathematik und Metaphysik bei Aristoteles: Akten des X. Symposiums Aristotelicum, Sigriswil, 6.–12. September 1984* (Bern and Stuttgart: Paul Haupt, 1987, 332 pp.). See also item 1106. For the Aristotelean legacy in the Middle Ages see Charles B. Crowley *Universal Mathematics in Aristotelian-Thomistic Philosophy: The Hermeneutics of Aristotelian Texts Relative to Universal Mathematics* (Washington: University Press of America, 1980, xviii + 221 pp.).

4105. Heinzmann, Gerhard. *Poincaré, Russell, Zermelo et Peano. Textes de la discussion (1906–1912) sur les fondements des mathématiques: des antinomies à la prédicativité*. Paris: Blanchard, 1986, 332 pp.

The volume compiles reprints of the discussion between Poincaré, Russell, Zermelo and Peano on possible solutions of the antinomies and the axiomatization of set theory.

4106. Heinzmann, Gerhard. *Zwischen Objektkonstruktion und Strukturanalyse. Zur Philosophie der Mathematik bei J. H. Poincaré*. Göttingen: Vandenhoeck & Ruprecht, 1995, 166 pp.

From the standpoint of Peircean pragmatism the author gives interpretations of Poincaré's philosophies of geometry, logic, set theory and arithmetic.

4107. Herbrand, Jacques. *Logical Writings*. Edited and translated by W. D. Goldfarb Dordrecht: Reidel; Cambridge, Mass.: Harvard University Press, 1971, vii + 312 pp.

Herbrand's essays are on the axioms of arithmetic, the fundamental problem in mathematics, on proof theory, Hilbert's logic, the consistency of arithmetic. They show a purely formal approach towards Hilbert's program.

4108. Heyting, A. *Intuitionism: An Introduction*. Amsterdam: North-Holland, 1956, viii + 132 pp., 3rd rev. ed., 1980.

Written by Brouwer's chief disciple, this introduction to intuitionism contains a dialogue contrasting intuitionist and other views on the philosophy of mathematics, as well as a detailed exposition of intuitionistic concepts applied to algebra, geometry, analysis, and mathematical logic.

4109. Hilbert, David. "Neubegründung der Mathematik". *Abhandlungen aus dem mathemtischen Seminar der Hamburgischen Universität* 1 (1922), 157–177. Reprinted in *Gesammelte Abhandlungen*. Vol. 3. Berlin: Springer, 1935, 157–177, item 424.

Hilbert's first presentation of his thoughts on the foundations of arithmetic appeared in 1904, but it was not until 1922 that a much improved formulation of his ideas was published. The principal stimulus for returning to foundations in 1922 would seem to have been the constructivistic writings of Weyl, especially the 1921 paper "Über die neue Grundlagenkrise ..." (see annotation on Weyl, item 4173). According to Hilbert, Weyl did not detect a vicious circle in the usual methods of concept formation in analysis; rather, he showed that a circle would occur if the usual methods were employed from a constructivistic basis like Weyl's (see also Hilbert and Ackermann, *Grundzüge der theoretischen Logik* [Berlin: Springer, 1928], chapter 4, sections 5 and, especially, 9—this material does not occur in later editions). "The vicious circle is artificially brought into analysis by Weyl." Hilbert vigorously emphasized that analysis was not uncertain and its foundations were not unstable; Weyl's representations did not correspond to the real facts. Moreover, it was Hilbert's opinion that the constructive tendency has been misdirected by Brouwer and Weyl. A constructive mathematics should not replace the classical; the constructive tendency should be applied to attain incontestible consistency proofs for the axiomatized classical systems, which would restore the reputation for absolute certainty enjoyed by mathematics before the antinomies and put an end to controversy once and for all. Hilbert's 1925 paper,"On the Infinite", included in the volumes edited by Benacerraf and Putnam, item 4049, and by van Heijenoort, items 3097, 4167, is also of considerable interest for the philosophy of mathematics. The context of Hilbert's early philosophy of mathematics up to the First World War is presented in Peckhaus *Hilbertprogramm und Kritische Philosophie* (item 3178).

4110. Hintikka, Jaakko, ed. *The Philosophy of Mathematics.* Oxford: Oxford University Press, 1969, 186 pp.

By means of his selection of eleven essays, the editor argues that a true understanding of the philosophy of mathematics can only be based on an adequate understanding of mathematical logic. The essays themselves are by L. Henkin (completeness of first-order and higher-order logics), R. Smullyan (self-reference), G. Kreisel (informal rigor), S. Feferman (predicative analysis), K. Gödel (intuitionistic logic), H. Rogers (computability), A. Robinson (metaphysics of the calculus), and A. Tarski (first-order geometry).

4111. Hintikka, Jaakko, ed. *From Dedekind to Gödel. Essays on the Development of the Foundation of Mathematics.* Dordrecht: Kluwer, 1995, x + 459 pp.

This volume contains fourteen essays on 19th and early 20th century philosophy of mathematics. The contributions are by J. Webb, on the role of contradiction in the development of geometry, J. Hintikka on standard vs. nonstandard distinction, H. M. Edwards on Kronecker, D. C. McCarty on Dedekind, C. O. Hill on Frege's correspondence, and in a further paper on "Husserl and Hilbert on Completeness", R. G. Heck Jr.

on "Frege's Principle", P. Ehrlich on H. Hahn's contributions to the development of the modern theory of magnitudes, G. H. Moore on the origins of Russell's paradox, A. Kanamori on "The Emergence of Descriptive Set Theory", J. van Plato on the roots of modern probability theory, W. Boos on some metaphysical ideas of T. Skolem and H. Weyl, J. Woleński on "Tarski's Background", M. Marion on Wittgenstein and Ramsey on identity, J. Floyd on Wittgenstein, Gödel and the trisection of the angle, and D. Føllesdal on Gödel and Husserl.

4112. Hintikka, Jaakko. *The Principles of Mathematics Revisited.* Cambridge, New York, Melbourne: Cambridge University Press, 1996, xii + 288 pp.

Hintikka uses his tool of an independence friendly, first-order predicate logic to reconsider the classical topics of the philosophy of mathematics, such as paradoxes, completeness, negation, truth definitions, axiomatic set theory and constructivism.

4113. Janich, Peter. *Euklids Erbe. Ist der Raum dreidimensional.* München: C. H. Beck, 1989, 246 pp. English translation by David Zook as *Euclid's Heritage: Is Space Three-dimensional?* Dordrecht, Boston, London: Kluwer, 1992, xii + 227 pp.

Janich gives a proof for the three-dimensionality of space in the spirit of the methodological constructivism by reconstructing our speaking about spatial forms of bodies. In a first part he gives a detailed discussion of earlier attempts to explain the three-dimensionality of space, in particular the "purely spatial approach" (Aristotle, Euclid, Galileo), the approach to ground three-dimensionality in motion (I. Kant, P. Natorp, F. A. Trendelenburg, W. K. Clifford), the approach from laws of force (Kant, P. Ehrenfest), "causalistic" explanations (H. Brotman, R. Carnap), and "biological and perception-theoretical approaches" (H. Poincaré, J. von Uexküll). A form-theoretic foundation of Euclidean Geometry was provided by Paul Lorenzen, *Elementargeometrie. Das Fundament der Analytischen Geometrie* (Mannheim et al.: Bibliographisches Institut, 1984, 238 pp.), and R. Inhetveen in his *Konstruktive Geometrie. Eine formentheoretische Begründung der euklidischen Geometrie* (Mannheim, Wien, Zürich: B.I.-Wissenschaftsverlag, 1983, 175 pp.).

4114. Jesseph, Douglas M. *Berkeley's Philosophy of Mathematics.* Chicago: University of Chicago Press, 1993, xii + 322 pp.

The author describes and discusses Berkeley's philosophy of mathematics starting from Berkeley's basic desire to avoid abstractions and to interpret mathematics as a part of his general theory of signs.

4115. Kambartel, Friedrich. *Erfahrung und Struktur. Bausteine zu einer Kritik des Empirismus und Formalismus.* Frankfurt a.M., 1968, 260 pp.

The author discusses Carnap's thesis that every language can be reduced to a formal language. The author's approach is motivated by the systematical question whether empiricism as a theory of subsequent concept formation related to objects given immediately. Structural concepts and formalistic positions are discussed. The book contains sections on Locke's empiricism, the Hilbert-Frege controversy, G. Cantor's set theory, and on operative arithmetic (Lorenzen).

4116. Kambartel, Friedrich. "Frege und die axiomatische Methode. Zur Kritik mathematikhistorischer Legitimationsversuche der formalistischen Ideologie". In *Frege und die moderne Grundlagenforschung. Symposium, gehalten in Bad Homburg im Dezember 1973.* Edited by C. Thiel Meisenheim am Glan, 1975, 77–89. Reprinted in Matthias Schirn, ed. *Studien zu Frege I. Logik und Philosophie der Mathematik / Studies on Frege I. Logic and Philosophy of Mathematics.* Stuttgart-Bad Cannstatt: Fromman-Holzboog, 1976, 215–228.

4117. Kitcher, Philip. *The Nature of Mathematical Knowledge.* New York and Oxford: Oxford University Press, 1983, xii + 287 pp.

The author gives a theory about mathematical knowledge, rejecting the standard apriorism and attempting to give a detailed articulation of its alternative, mathematical empiricism. He summarizes that his theory of mathematical knowledge "traces the knowledge of the contemporary individual, through the knowledge of her authorities, through a chain of prior authorities, to perceptual knowledge acquired by our remote ancestors" (p. 7). Mathematical change forms a major topic in this book which ends with a case study on the development of analysis.

4118. Knobloch, Eberhard. "Einfluß der Symbolik und des Formalismus auf die Entwicklung des mathematischen Denkens". *Berichte zur Wissenschaftsgeschichte* 3 (1980), 77–94.

With the help of historical examples the following aspects of the use of the mathematical symbolic language are discussed: compactness and simultaneity, problem-solving and generalization, heuristics and progress, mechanism and calculations, formalism.

4119. Knobloch, Eberhard. "Symbolik und Formalismus im mathematischen Denken des 19. und beginnenden 20. Jahrhunderts". In *Mathematical Perspectives. Essays on Mathematics and Its Historical Development. Presented to Professor Dr. Kurt-Reinhard Biermann on the Occasion* *of His 60th Birthday.* Edited by J. W. Dauben New York et al.: Academic Press, 1981, 139–165.

The paper tells the story of the emergence of abstract algebra and vector analysis in the 19th and the 20th centuries regarded as the roots of logicism and formalism focussing on the influence of advances in mathematical symbolism. The following aspects are touched: heuristic and the principles of order, symbolic algebra and formal mathematics, Hamilton, and the theory of quaternions, operational calculus, algorithmization, universalization.

4120. König, Gert, ed. *Konzepte des mathematisch Unendlichen im 19. Jahrhundert.* Göttingen: Vandenhoeck & Ruprecht, 1990, 273 pp.

This volume presents 10 papers discussing 19th century conceptions of mathematical infinity as proposed by Euler and Cauchy (D. Laugwitz), Lagrange (P. Dugac), the Paris discussion, 1800–1830, (I. Grattan-Guinness), Hegel (W. Bonsiepen), his relation to Cavalieri (A. Moretto) and to Lagrange (A. Klaucke), J. F. Fries (G. Schubring), Herbart (H. N. Jahnke), Bolzano (D. D. Spalt), and H. Grassmann, Bolzano and Frege (M. Otte).

4121. Koetsier, Teun. *Lakatos' Philosophy of Mathematics. A Historical Approach.* Amsterdam et al.: North Holland, 1991, xii + 312 pp.

The author proposes to modify Lakatos's Methodology of Scientific Research Programs into a Methodology of Scientific Research Traditions. Research traditions concern a particular fundamental mathematical domain and are characterized by the entities that are being studied in that domain and by assumptions about the appropriate method by which the properties can be proved. The range of this conception is shown with the help of rational reconstructions of historical developments in Greek mathematics, analysis and the theory of partial differentiations.

4122. Krämer, Sybille. *Symbolische Maschinen. Die Idee der Formalisierung in geschichtlichem Abriß.* Darmstadt: Wissenschaftliche Buchgesellschaft, 1988, viii + 227 pp.

This book gives a comprehensive survey of the history of algorithmic thinking from ancient Egypt mathematics to Turing machines.

4123. Krämer, Sybille. *Berechenbare Vernunft. Kalkül und Rationalismus im 17. Jahrhundert.* Berlin, New York: Walter de Gruyter, 1991, x + 431 pp.

Systematical and historical aspects of the idea of calculating as operating with signs are discussed. The author starts with the calculus in ancient Greek mathematics and in the early algebra (calculating with letters). The main focus is, however, the calculus in rationalistic philosophy (Descartes, Leibniz), when symbolic techniques were developed.

4124. Lakatos, I., ed. *Problems in the Philosophy of Mathematics.* Amsterdam: North-Holland, 1967, second printing 1972, xv + 241 pp.

This collection of essays, the proceedings of an international colloquium, offers a diversity of approaches to the history of the philosophy of mathematics. A. Szabó discusses the Eleatics vis-à-vis the rise of Greek axiomatics, while A. Robinson considers the history of the calculus from the standpoint of non-standard analysis. F. Sommers analyzes Frege's use of quantification, S. Körner ponders on the effect on philosophy of twentieth-century mathematical logic, and G. Kreisel argues for the value of informal rigor. Last, P. Bernays and A. Mostowski discuss how P. Cohen's results have affected the foundations of mathematics. Each essay has several commentaries, together with the essayist's reply.

4125. Lakatos, I. *Proofs and Refutations: The Logic of Mathematical Discovery.* Edited by J. Worrall and E. Zahar. Cambridge: Cambridge University Press, 1976, xii + 174 pp. Reprinted, 1995.

Influenced by G. Pólya and K. Popper, this book argues for a dialectical approach to the history of proofs in mathematics. Two case studies provide evidence for the thesis that mathematics grows by proof, counterexample, then revised proof. For applications outside foundational studies see David Corfield, "Assaying Lakatos's Philosophy of Mathematics". (*Studies in the History and Philosophy of Science* 28 [1997], pp. 99–121).

4126. Lavine, Shaughan. *Understanding the Infinite.* Cambridge, Mass., and London: Harvard University Press, 1994, vi + 372 pp.

This book aims at an understanding of the infinite as mirrored by the development of set theory and based on mathematical intuition.

4127. Lewis, C. I. *A Survey of Symbolic Logic.* Berkeley: University of California Press, 1918, vi + 406 pp. Corrected republication with the omission of chapters V and VI, New York: Dover, 1960, x + 327 pp.

This book is at once a history of symbolic logic—discussing the Boole–Schröder algebra of logic on the one hand and the Peano-Russell logistic on the other—and a summary of the author's results on modal logic. It concludes with the most comprehensive bibliography of research in symbolic logic up to 1918. See also item 3209.

4128. Mac Lane, Saunders. *Mathematics: Form and Function.* New York et al.: Springer-Verlag, 1986, xii + 476 pp.

The author attempts to enlarge the standard view on the philosophy of mathematics based on different foundational positions towards a closer connection to what is actually present in the practice and in the formalism of mathematics. By revisiting several mathematical fields he gives a philosophical introduction to the structural view on mathematics.

4129. Maddy, Penelope. *Realism in Mathematics.* Oxford: Clarendon Press, 1990. Paperback edition with corrections, 1992.

The author reconsiders mathematical intuition, the number concept, set theory and axiomatization, monism and nominalism from the standpoint of mathematical realism, i.e. the opinion that "mathematics is the scientific study of objectively existing mathematical entities just as physics is the study of physical entities" (p. 21).

4130. Maddy, Penelope. *Naturalism in Mathematics.* Oxford: Clarendon Press, 1997, x + 254 pp.

This is a sequel (and a revision) of her earlier book on *Realism in Mathematics*, both books aiming at a justification of set theory. The author writes on the distinction between realism and naturalism: "While the realist undertakes to determine the truth or falsity of independent set theoretic statements in the objective world of sets, the naturalistic methodologist ignores these issues to focus instead on the advantages and disadvantages of these statements as means towards particular mathematical goals" (p. 233).

4131. Mancosu, Paolo. *Philosophy of Mathematics and Mathematical Practice in the Seventeenth Century.* New York and Oxford: Oxford University Press, 1996, x + 275 pp.

The book contains a very rich presentation of problems in the philosophy of mathematics as discussed in the 17th century, particularly the range of the "mathematical method", the problem of indivisibles (B. Cavalieri, P. Guldin), R. Descartes's *Géometrie*, the problem of continuity, paradoxes of the infinite, and G. W. Leibniz's differential calculus and its opponents. The appendix provides a translation of G. Biancani's *De Mathematicarum Natura* (1615).

4132. Mancosu, Paolo. *From Brouwer to Hilbert. The Debate on the Foundations of Mathematics in the 1920s.* New York and Oxford: Oxford University Press, 1998, xii + 337 pp.

In four parts this volume provides basic texts of the foundational crisis of mathematics in the 1920s. Part I gives a selection of 6 papers by L. E. J. Brouwer. It is introduced by W. P. van Stigt ("Brouwer's Intuitionist Programme"). Part II is devoted to H. Weyl, containing texts by Weyl, Brouwer, and O. Hölder. The introduction "Hermann Weyl: Predicativity and an Intuitionistic Excursion" was written by Mancosu. Part III compiles texts by D. Hilbert and P. Bernays on Metamathematics. In part IV, on intuitionistic logic, texts by Brouwer, E. Borel, V. Glivenko, A. Heyting, and A. Kolmogorov are printed and introduced by Mancosu and van Stigt.

4133. Marciszewski, Witold, and Roman Murawski. *Mechanization of Reasoning in a Historical Perspective.* Amsterdam, Atlanta: Rodopi, 1995, 267 pp.

The authors give a survey of the dream of mechanical reasoning from the formalization of arguments in the Middle Ages to the mechanized deductive systems of our time, focussing on the development of symbolic logic from Leibniz to Gentzen and considering its relation to cognition theory and artificial intelligence.

4134. Martin, Gottfried. *Arithmetik und Kombinatorik bei Kant.* Dissertation at Freiburg i. Br. 1934, Itzehoe, 1938, 102 pp. Enlarged edition Berlin: De Gruyter, 1972, 165 pp.

Martin gives an interpretation of Kant's ideas on arithmetic and on combinatorics from the viewpoint of Hilbert's program. It is valuable because of its selection of relevant texts.

4135. Mehrtens, Herbert. *Moderne–Sprache–Mathematik. Eine Geschichte des Streits um die Grundlagen der Disziplin und des Subjekts formaler Systeme.* Frankfurt a.M.: Suhrkamp, 1990, 640 pp.

Mehrtens gives a very stimulating interpretation of the foundational debates in the end of the 19th century and the beginning of the 20th century. He reconstructs them as arguments between representatives of "modern mathematics" (D. Hilbert, G. Cantor, E. Zermelo, F. Hausdorff) and anti-modern mathematics (L. Kronecker, F. Klein, H. Poincaré, and L. E. J. Brouwer). The book furthermore presents a socio-historical analysis of the cultural and institutional modernization of mathematics after 1900 in Germany and a postmodern inspired analysis of the language of mathematics. Mehrtens's thesis that the sharp distinction between mathematics and philosophy is one basic mark of Hilbert style modern mathematics can be doubted, however. Evidence for Hilbert's efforts to combine philosophical and mathematical research in the foundations of mathematics is given by V. Peckhaus in his paper "Hilbert's Axiomatic Programme and Philosophy", in *The History of Modern Mathematics*, Vol. 3, edited by E. Knobloch and D. E. Rowe (Boston et al.: Academic Press, 1994), 91–112.

4136. Mooij, J. J. A. *La philosophie des mathématiques de Henri Poincaré.* Paris: Gauthier-Villars, 1966, 174 pp.

A comprehensive historical treatment of the background, context, and content of Poincaré's philosophy of mathematics, including his philosophy of geometry. In particular, the relation of Poincaré's philosophy to Kant's is discussed and the views of the logicists are expounded; a detailed coverage of the controversy between Russell and Poincaré is given, and there are chapters on Poincaré's criticisms of Hilbert and of Zermelo's set theory. Large bibliography.

4137. Mostowski, Andrzej. *Thirty Years of Foundational Studies.* New York: Barnes & Noble, 1966, 180 pp.

This is a selection of Mostowski's lectures on the development of mathematical logic and the study of the foundations of mathematics in 1930–1964. See items 3189.

4138. Nagel, Ernest. " 'Impossible Numbers': A Chapter in the History of Modern Logic". *Studies in the History of Ideas.* Vol. 3. New York: Columbia University Press, 1935, 429–474. Reprinted in E. Nagel. *Teleology Revisited and Other Essays in the Philosophy and History of Science.* New York: Columbia University Press, 1979; (second edition, 1982),166–194.

Describes attempts to interpret various extended number systems in the transition in which "mathematics has grown from having been the science of quantity to becoming the science which explores the most abstract properties of any subject matter whatsoever." Ideas of Euler, Wallis, Playfair, Peacock, D. Gregory, De Morgan, Hamilton, and G. Boole are discussed. See also items 2570.

4139. Nagel, Ernest. "The Formation of Modern Conceptions of Formal Logic in the Development of Geometry". *Osiris* 7 (1939), 142–224. Reprinted in *Teleology Revisited*, item 4138, 195–259.

Discusses philosophically interesting mathematical developments in geometry during the 19th century. Nagel briefly examines the reasons which emerged for rejecting the component of the traditional conception of geometry according to which it is "an inherently quantitative science." He then proceeds to a more thorough presentation of matters bearing on the thesis that geometry is "the science of extension or space." Also considered are "the consequent reorientations provoked by this material to the traditional claim that geometry is an a priori science." Among the ideas discussed are those of Gergonne, Poncelet, Hermann Grassmann, von Staudt, Chasles, Plücker, Helmholtz, Pasch, Klein, Hilbert, and Poincaré. Numerous references.

4140. Parsons, Charles. *Mathematics in Philosophy. Selected Essays.* Ithaca and New York: Cornell University Press, 1983, 365 pp.

Topics include mathematical ontology, interpretations of Kant, Frege, and Quine, considerations on sets and classes, modalities and the Liar Paradox.

4141. Peckhaus, Volker. *Logik, Mathesis universalis und allgemeine Wissenschaft. Leibniz und die Wiederentdeckung der formalen Logik im 19. Jahrhundert.* Berlin: Akademie Verlag, 1997, xii + 412 pp.

This book is on the Leibnizian ideas concerning logic and a universal mathematics and their role in the emergence of modern logic in the second half of the 19th century. This creation of the new logic was initially independent from the conceptions of the rationalistic predecessor, but motivated by foundational problems in geometry and arithmetic.

4142. Penrose, Roger. *Shadows of the Mind. A Search for the Missing Science of Consciousness*. Oxford, New York and Melbourne: Oxford University Press, 1994, xvi + 457 pp.

The author relates mathematics, (quantum) physics and the philosophy to mind in order to combine them in the enterprise to understand the mind, and above all consciousness. He is particularly interested in the role of computation and the effects of non-computability in various relevant domains.

4143. Poincaré, Henri. *The Foundations of Science*. Translated by G. B. Halsted. Lancaster, Pa.: The Science Press, 1913, Reprinted Washington, D.C.: University of America Press, 1982, xi + 553 pp.

The original version (1893) of the chapter, "The Nature of Mathematical Reasoning," written well before the controversy with the logicists and Cantorists, apparently in ignorance of the work of Dedekind and Frege on the foundations of arithmetic, presents the view that the natural numbers are indefinable and the principle of induction is synthetic a priori. The question of the nature of mathematics is pursued in terms of the opposing views of Leibniz and Kant, with Poincaré defending the position of Kant. Later he would combat the new Leibnizians, the logicists, and continue to espouse a Kantian view. Thus, in "Mathematics and Logic," the original version of which appeared in 1905, the question raised is "whether . . . once the principles of logic are admitted we can . . . demonstrate all mathematical truths without making a fresh appeal to intuition"; his answer is no. This drew replies from Couturat and Russell. An account of the circumstances of the controversy is given by P. Jourdain in *The Monist* 23 (1912), 481–483, and a translation of Couturat's paper "For Logistic" appears there, pp. 483–523. The paper by Russell is included in *Essays in Analysis* (see annotation for item 4153 below). Poincaré was also critical of Hilbert for apparently having to use complete induction to establish the consistency of a system containing an axiom of complete induction. There is a reply by Hilbert in his "Neubegründung der Mathematik" (1922), see item 4109 above; see also the annotations to the van Heijenoort volume, items 3097 and 4167. Though Poincaré was a forerunner of intuitionism, he held that in mathematics *existence* means "exemption from contradiction." For this, he was reprimanded by Brouwer in 1907; see item 4058.

4144. Poincaré, Henri. *Dernières pensées*. Paris: E. Flammarion, 1913, 258 pp. English translation by J. Bolduc. *Mathematics and Science, Last Essays*. New York: Dover, 1963.

Contains Poincaré's later essays "The Logic of Infinity" and "Mathematics and Logic". The former is critical of the 1908 systems of

Russell and of Zermelo; his objection to Russell is that he seems to employ the theory of numbers in describing the system of logical types and that the axiom of reducibility is unclear and lacks justification, and to Zermelo, that his axioms are arbitrary. In "Mathematics and Logic," Poincaré discusses the views he calls "pragmatism" (his own) and "Cantorism." Pragmatists consider only objects which are finitely definable and recognize as meaningful theorems only those which are "verifiable."

4145. Poincaré, Henri. *Science et méthode*. Paris: Flammarion, 1908, 314 pp. English translation by F. Maitland with an introduction by B. Russell as *Science and Method*, London: Thomas Nelson & Sons, 1914, xi + 288 pp. Reprinted Bristol: Thoemmes, 1996 .

This collection of provocative essays includes his three polemics against the logics of Peano, Russell, and Hilbert, as well as his seminal essay on the psychology of mathematical creation.

4146. Pólya, Georg. *Mathematics and Plausible Reasoning*. Vol. 1: *Induction and Analogy in Mathematics*, Princeton, N.J.: Princeton University Press, 1954, Vol. 2: *Patterns of Plausible Inference*. Princeton, N.J.: Princeton University Press, 1954. Second edition, 1968.

The first volume discusses the methods of induction and plausible reasoning (as complement to the usual demonstrative reasoning) in mathematics. The second volume examines the structure of plausible reasoning and its role in Probability Theory and in mathematics education.

4147. Posy, Carl J., ed. *Kant's Philosophy of Mathematics. Modern Essays*. Dordrecht, Boston, London: Kluwer, 1992.

This volume contains four classical papers from the 1960s and 1970s by J. Hintikka, C. Parsons, M. Thompson and P. Kitcher and nine recent papers by C. Parsons, J. M. Young, M. Friedman, S. Barker, A. Melnick, W. Harper, C. J. Posy, G. G. Brittan, Jr., and J. Hintikka.

4148. Puhl, Klaus, ed. *Wittgenstein's Philosophy of Mathematics. Proceedings of the 15th International Wittgenstein-Symposium. 16th to 23rd August 1992. Kirchberg am Wechsel (Austria).* Vol. 2. Vienna: Verlag Hölder-Pichler-Tempsky, 1993, 315 pp.

This second volume of the proceedings (for the first volume see item 4068) consists of 33 papers, among them the plenary lectures by H. Wang, J. Hintikka, P. Maddy, and M. Wigley. 11 papers of section I concern Wittgenstein's philosophy of mathematics, another 7 papers deal with Wittgenstein's *Tractatus Logico-Philosophicus*.

4149. Ramsey, Frank Plumpton. *Foundations. Essays in Philosophy, Logic, Mathematics and Economics.* Edited by D. H. Mellor. Atlantic Highlands, N.J., 1978.

This selection includes Ramsey's famous article "The Foundations of Mathematics", from *Proceedings of the London Mathematical Society*, 2nd ser. 25 (1926), 338–384.

4150. Resnik, Michael D. "The Frege-Hilbert Controversy". *Philosophy and Phenomenological Research* 34 (1974), 386–403.

The controversy concerned the nature of the axiomatic method, and, in particular, its application in foundations of geometry. One main issue was the sense (if any) in which axiom systems can constitute definitions. The author provides a clear presentation of the issues and of the strengths and weaknesses of Frege's criticisms of Hilbert. In "Frege und die axiomatische Methode. Zur Kritik mathematikhistorischer Legitimationsprobleme der formalistischen Ideologie" (in *Frege und die moderne Grundlagenforschung*, edited by C. Thiel, Meisenheim a. Glan: Hain, 1975, 77–89) Friedrich Kambartel argued that Frege was the first who had a methodologically justified understanding of the axiomatic method. The sources involved—the correspondence, the articles on foundations of geometry by Frege, as well as an article in defense of Hilbert by A. Korselt—are translated by E. W. Kluge in *Gottlob Frege on the Foundations of Geometry and Formal Theories of Arithmetic* (New Haven: Yale University Press, 1971).

4151. Resnik, M. D. *Frege and the Philosophy of Mathematics.* Ithaca: Cornell University Press, 1980, 244 pp.

This full-length study of Frege includes but supersedes Resnik's essay on the Frege-Hilbert controversy (see item 4150). Here the author also discusses Frege's criticisms of psychologism, formalism, and empiricism, and analyzes Frege's larger philosophy of mathematics.

4152. Resnik, Michael D. *Mathematics as a Science of Patterns.* Oxford: Clarendon Press, 1997, xiii + 285 pp.

The author presents his realistic (being a kind of structuralistic) view on ontological and epistemological aspects of mathematics regarded as a science of patterns. He relates his approach to concurring positions and deals with problems of mathematical epistemology (such as the distinction between mathematics and sciences), holism, and mathematical evidence. Mathematical objects are introduced as positions in patterns.

4153. Russell, Bertrand. *Essays in Analysis.* Edited by D. Lackey. London: George Allen & Unwin, 1973, 345 pp.

Contains fifteen of Russell's papers from the period 1904–1913, dealing with his views on classes, the antinomies and various ways of avoiding or solving them, the axiom of choice, the axiom of infinity, and other matters relating to the philosophy of mathematics. Some previously unpublished manuscripts are also included. Russell's articles of 1906 and 1910 replying to Poincaré appear here in English versions; the latter is almost identical to the second chapter of the introduction to *Principia Mathematica*. The article, "The Axiom of Infinity" (1904), was written before Russell had fixed on a method of avoiding the antinomies which required a special hypothesis of infinity; it maintains that the existence of an infinite class is provable. At the time Russell favored some form of the "zig-zag" theory, which is described as a possibility of avoiding the antinomies, in "Some Difficulties in the Theory of Transfinite Numbers and Order Types" (1906), also reprinted in this collection. Historical introductions to main sections of the book are provided by the editor. An appendix contains a bibliography of all Russell's published and unpublished writings on logic. Complete bibliographical information on Bertrand Russell's publications can be obtained from the comprehensive *A Bibliography of Bertrand Russell* by Kenneth Blackwell and Harry Ruja (3 vols., London and New York: Routledge, 1994, lvi + 611 pp.; xiv + 575 pp; xii + 305 pp.). *The Collected Papers of Bertrand Russell*, presently being prepared by the Russell Editorial Project at McMaster University, will eventually supersede this item. Volume 6 *Logical and Philosophical Papers 1909–13*, edited by John G. Slater (London and New York: Routledge, 1992) has already been published. Part 1 (pp. 3–74) with 9 papers is devoted to "Logic and the Philosophy of Mathematics."

4154. Russell, Bertrand. *The Principles of Mathematics*. First ed., Cambridge: Cambridge University Press, 1903. Second ed., London: Allen and Unwin, 1937, xxix + 534. Paperback edition, London: Routledge, 1992.

Contains Russell's most extensive philosophical presentation of logicism, discussions of the work of many of his predecessors, an explanation of his famous antinomy, attempts to deal with the antinomies, including an appendix on the theory of types, his analysis of the various number concepts, an exposition of his logic of relations, and much else. It is a work in which theories are expounded to a certain point, dropped, then, later, something else is tried; it is not an exposition of finished thoughts, but is exploratory; experimenting with ideas, Russell is struggling with problems new and difficult, and *Principles* is the record of his thoughts up to late 1902. Russell thought he was laying mathematical foundations for mathematics in place of the nonsense of idealistic philosophers and refuting the Kantian philosophy of mathematics. "Philosophy asks of Mathematics: What does it mean? Mathematics in the past was unable to answer, and Philosophy answered by introducing the totally irrelevant notion of mind. But now Mathematics is able to answer, so far at least as to reduce the whole of its propositions to certain fundamental notions of logic." The view that "mathematical reasoning is not strictly formal, but always uses intuitions" was the Kantian doctrine which Russell believed "capable of a final and irrevocable refutation." He did not, at the time of *Principles*, oppose the doctrine that mathematics is in some sense synthetic. A comprehensive selection of material from the Russell Archives surrounding the preparation of this book was published as volume 3 of *The Collected Papers of Bertrand Russell*, edited by Gregory H. Moore, entitled *Toward the "Principles of Mathematics": 1900–02* (London and New York: Routledge, 1993, lviii + 895 pp.). The story of this book is told in the editor's informative introduction (pp. xiii–xlviii). See also Alejandro Ricardo Garciadiego Dantan, *Bertrand Russell and the Origins of the Set-theoretic 'Paradoxes'* (Basel, Boston, Berlin: Birkhäuser, 1992, xxix + 264 pp.).

4155. Schirn, Matthias, ed. *Frege: Importance and Legacy*. Berlin and New York: Walter de Gruyter, 1996, x + 466 pp.

Ten papers and the introduction of this collection of sixteen papers deal with G. Frege's logic and philosophy of mathematics (the others deal with epistemology and philosophy of language). They include M. Schirn's introduction to Frege and the foundations of arithmetic and geometry, M. D. Resnik, M. Schirn, B. Hale and C. Wright on logical and mathematical objects, R. G. Heck on definition by induction, G. Boolos on the paradoxes with a reply by M. Dummett, C. Thiel on the structure of Frege's *Grundgesetze der Arithmetik*, P. Simons on the horizontal, and F. von Kutschera on natural deduction.

4156. Schirn, Matthias, ed. *The Philosophy of Mathematics Today*. Oxford: Clarendon Press, 1998, xii + 638 pp.

This collection of twenty papers by prominent authors has its origins in a conference which took place in Munich in 1993. It surveys recent approaches of analytic philosophy to the philosophy of mathematics in the following fields: "Ontology, models and indeterminacy" (five papers), "Mathematics, science, and method" (four papers), "Finitism and intuitionism" (three papers), "Frege and the foundations of arithmetic" (five papers), "Sets, structure, and abstraction" (three papers).

4157. Schulz, Klaus-Dieter. *Die These von Church. Zur erkenntnistheoretischen und sprachphilosophischen Bedeutung der Rekursionstheorie*. Frankfurt a.M. et. al.: Peter Lang, 1997, 318 pp.

This book gives a comprehensive overview on the history and philosophy of the concept of recursion. It is centered around Church's thesis according to which all effectively calculable functions are recursive.

4158. Segre, Michael. "Peano's axioms in their historical context". *Archive for the History of Exact Sciences* 48 (1994), 201–342.

This paper is a full-scale study on Peano's philosophy of mathematics concentrating on the mathematical and logical contexts of his axiomatization of arithmetic.

4159. Sieg, Wilfried. "Hilbert's Program Sixty Years Later". *Journal of Symbolic Logic* 53 (1988), 338-348.

The author discusses two directions in which foundational research in the spirit of Hilbert's program went: the relative consistency proofs and the reductive program of constructive mathematics. Two further important papers on Hilbert's program (all of them delivered at a conference at Washington, D.C., in December 1985) are published on subsequent pages, Stephen G. Simpson's "Partial Realizations of Hilbert's Program" (349–363), and Solomon Feferman, "Hilbert's Program Relativized: Proof-Theoretical and Foundational Reductions" (364–384).

4160. Sjöstedt, C. E., ed. *Le axiomes de paralleles de Euclides a Hilbert. Un probleme cardinal in le evolution del geometrie.* Stockholm: Bokförlaget Natur och Kultur, 1968, v + 939 + 7 + 14 pp.

This book gives facsimile reprints of classical texts on the parallel axiom from Euclid (with reproductions of early manuscripts) to Einstein. All original texts are accompanied by translations into the international auxiliary language Interlingue. The book ends with two appendices on this language.

4161. Skolem, Thoralf. *Selected Works in Logic.* Edited by Jens Erik Fenstad. Oslo, Bergen and Tromsö: Universitetsforlaget, 1970, 732 pp.

This volume contains, in addition to papers on logic and the philosophy of mathematics, a biography of Skolem by Fenstad, J. and a detailed historical study by H. Wang.

4162. Tarski, Alfred. *Logic, Semantics, Metamathematics: Papers from 1923 to 1938.* Edited by J. H. Woodger. Oxford: Clarendon Press, 1956, xiv + 472 pp. Rev. ed. by J. Corcoran. Indianapolis: Hackett, 1980; second edition, second printing, 1990.

Not a history, this work contains the translation into English of many of the most significant articles by one of this century's best logicians. Particularly useful is the translation of "The Concept of Truth in Formalized Languages" (Polish 1933, German, enlarged, 1935). See J. Etchemendy, "Tarski on Truth and Logical Consequence", *Journal of Symbolic Logic* 53 (1988), 51–79.

4163. Thiel, Christian. *Philosophie und Mathematik. Eine Einführung in ihre Wechselwirkungen und in die Philosophie der Mathematik.* Darmstadt: Wissenschaftliche Buchgesellschaft, 1995, viii + 364 pp.

This book covers a wide range of philosophical topics which arose from the relations and interdependencies between philosophy and mathematics. It is guided by the question, what could be the lasting task of a philosophy of mathematics which would not lose its significance for the development of mathematics. Using partially a historical approach the author treats the "object" of mathematics, the problem of mathematical applications, ways of mathematical thinking, the relation between mathematics, logic and metamathematics, the concept of number, construction and abstraction, infinite domains, diagonal procedure, continuum and transfinite numbers, axiomatic and formal systems, the restrictions of the axiomatic method, "finite" and "constructive" methods, the concept of structure in mathematics, geometry as a theory of forms, fundamentalism, antinomies and paradoxes, and the foundational crisis.

4164. Tonietti, Tito. "Four Letters of E. Husserl to H. Weyl and their Context". In *Exact Sciences and Their Philosophical Foundations. Exakte Wissenschaften und ihre philosophische Grundlegung. Vorträge des Internationalen Hermann-Weyl-Kongresses, Kiel 1985.* Edited by Wolfgang Deppert et al., Frankfurt a.M. et al., 1988, 343–384.

The author discusses the four letters of an exchange between Edmund Husserl and Hermann Weyl which were written between 1918 and 1931. They prove the important influence of Husserl on Weyl. The letters are published by Dirk van Dalen in "Four Letters from Edmund Husserl to Hermann Weyl", *Husserl Studies* 1 (1984), 1–12.

4165. Torretti, R. *Philosophy of Geometry from Riemann to Poincaré.* Dordrecht: Reidel, 1978, xiii + 459 pp. Paperback edition, 1984.

The four chapters of this substantial volume deal with "background information about the history of science and philosophy . . . the development of non-Euclidean geometries until . . . Klein's papers 'On the So-called Non-Euclidean Geometry' in 1871–73 . . . 19th-century research into the foundations of geometry . . . philosophical views about the nature of geometrical knowledge from John Stuart Mill to Henri Poincaré." The background information given includes such matters as Aristotle's theory of science and the nature of the Euclidean assumptions, which the author doubts were considered by Euclid to be self-evident truths. In additon to the account of philosophical thought, there is a good deal of mathematical exposition. Numerous notes and a large bibliography. See also item 3069.

4166. Tymoczko, Thomas, ed. *New Directions in the Philosophy of Mathematics.* Boston, Basel, Stuttgart: Birkhäuser, 1986, xvii + 323 pp.

This is an anthology against "foundationalism", i.e., the foundations approach in the philosophy of mathematics. The authors suggest to reexamine the actual practices of mathematicians and those who use mathematics. "This anthology delineates quasi-empiricism as a coherent and increasingly popular approach to the philosophy of mathematics" (p. xvi). Among the authors are R. Hersh, I. Lakatos, H. Putnam, R. Thom, N. D. Goodman, G. Pólya, H. Wang, P. H. Davis, R. L. Wilder, P. Kitcher, and T. Tymoczko.

4167. Van Heijenoort, Jean. *From Frege to Gödel. A Source Book in Mathematical Logic, 1879–1931.* Cambridge, Mass.: Harvard University Press, 1967, xi + 660 pp. Second printing, 1971.

Many of the papers collected here are of some relevance to philosophy of mathematics. Among these are Zermelo's 1908 "A New Proof . . .," in which he defends his 1904 proof of the well-ordering theorem against criticisms of, among other things, its use of the axiom of choice and impredicative definition; Russell's 1908 paper on type theory; Hilbert's "On the infinite" (1925); Skolem's 1922 "Some Remarks . . .," in which he asserts that "axiomatizing set theory leads to a relativity of set-theoretic notions, and this relativity is inseparably bound up with every thoroughgoing axiomatization"; Weyl's 1927 "Comments . . . ." Commenting on a paper by Hilbert, Weyl says "a few words in defense of intuitionism, which include a vindication of Poincaré's view on mathematical induction. The editor's introductions to the items of this selection provide an excellent historical and critical treatment of the issues involved in this controversial subject. See also item 3097.

4168. Volkert, Klaus Thomas. *Die Krise der Anschauung. Eine Studie zu den formalen und heuristischen Verfahren in der Mathematik seit 1850.* Göttingen: Vandenhoeck & Ruprecht, 1986, xxxi + 420 pp.

The author gives a survey on the role of intuition in mathematics, its crisis, and attempts to solve its problems.

4169. Waismann, Friedrich. *Einführung in das mathematische Denken. Die Begriffsbildung in der modernen Mathematik.* Vienna: Gerold, 1936, vii + 188 pp. Reprint of the second edition (1947), Darmstadt: Wissenschaftliche Buchgesellschaft, 1996.English translation by T. J. Benac, *Introduction to Mathematical Thinking. The Formation of Concepts in Modern Mathematics.* New York: Frederick Ungar, 1951. Reprinted New York: Harper & Row, 1966.

This book can be read as an interpretation of Wittgenstein's thoughts on the foundations of mathematics, inspired by his *Tractatus Logico-Philosophicus* (1921), but also by personal conversations. See also Waismann's *Lectures on the Philosophy of Mathematics*, edited by Wolfgang Grassl, (Amsterdam: Rodopi, 1982, 170 pp.), with an introduction to Waismann's philosophy by the editor.

4170. Wang, Hao. *Reflections on Kurt Gödel.* Cambridge, Mass.: MIT Press, 1987, xxvi + 336 pp.

This biography is written from the perspective of a long personal acquaintance between the author and Kurt Gödel. The second part on "Thoughts" (pp. 145–264) is devoted to Gödel's philosophy.

4171. Webb, Judson Chambers. *Mechanism, Mentalism, and Metamathematics.* Dordrecht: Reidel, 1980, xiii + 277 pp.

This book "is an essay on the significance of various metamathematical theorems, notably these of Gödel and Church on incompleteness and decidability, for both psychology and the philosophy of mathematics" (p. ix). Incompleteness is interpreted not "as our inability to formalize our notion of *number* as such, but rather as our inability to completely describe *the behavior of certain machines*" (ibid.)

4172. Wedberg, A. *Plato's Philosophy of Mathematics.* Stockholm: Almqvist & Wiskell, 1955, 154 pp. Reprinted New York: Greenwood, 1977, second printing, 1980.

Reconstructs Plato's philosophy of geometry and arithmetic in a way which is in agreement with Aristotle's description of Plato's doctrine. Wedberg compares and contrasts Plato's views with others common in his time as well as those common in recent times. In the case of arithmetic, from before Plato's time and long after, numbers were usually said to be pluralities of units; this is the definition used by Euclid and repeated for centuries. In postulating numbers as ideas, "Plato took within the framework of his idealistic system, essentially the same step which ... Frege took ... when he rejected the still current definitions of positive integers as sets of units ... ." For the broader context see D. H. Fowler, *The Mathematics of Plato's Academy: A New Reconstruction* (Oxford: Clarendon, 1999, xix + 401 pp.).

4173. Weyl, Hermann *Das Kontinuum. Kritische Untersuchungen über die Grundlagen der Analysis.* Leipzig: Veit, 1918, iv + 83 pp. Reprinted Berlin: de Gruyter, 1932. Translated by Stephen Pollard and Thomas Bole as *The Continuum: A Critical Examination of the Foundation of Analysis.* Kirksville, Miss., 1987, xxvi + 130 pp. Republished, unabridged and corrected, New York: Dover, 1994.The work was widely spread with the help of another edition *Das Kontinuum und andere Monographien.* New York: Chelsea, 1960; new printing, 1973; this edition contains as well the short monographs: H. Weyl *Mathematische Analyse des Raumproblems*, E. Landau *Darstellung und Begründung einiger neuerer Ergebnisse der Funktionentheorie*, B. Riemann *Über die Hypothesen, welche der Geometrie zugrunde liegen.*

Weyl's initial work in foundations (1910) aimed at making Zermelo's axiomatization of set theory more precise, but unsatisfactory attempts to eliminate the concept *finite number* from his explication of Zermelo's concept of *definite property*combined with his philosophical reflections led him to the conviction that Poincaré was right in holding iteration to be the ultimate foundation of mathematics. He also became convinced that concept formation in classical analysis was infected with a sort of vicious circularity. The "semi-intuitionistic" system of *Das Kontinuum* avoids this circularity by accepting the natural numbers as an infinite totality on the basis of which further sets and relations are predicatively constructed. A number of papers on philosophy of mathematics are contained in his *Gesammelte Abhandlungen*, edited by K. Chandrasekharan (Berlin: Springer, 1968, 4 vols.). Of particular note are "Der circulus vitiosus in der heutigen Begründung der Analysis" (1919), in which he tries to explain in the most direct way the nature of the vicious circle in analysis claimed in *Das Kontinuum*; "Über die neue Grundlagenkrise der Mathematik" (1921), which begins with an account of his 1918 system but proceeds to a lengthy explanation of Brouwer's intuitionism; and "Die heutige Erkenntnislage in der Mathematik" (1925), which contains a section on Hilbert. See also "Mathematics and Logic, A Brief Survey serving as Preface to a Review of *The Philosophy of Bertrand Russell*", *American Mathematical Monthly* 53 (1946), 2–13; the review appeared in the same volume, 208–214.

4174. Wittgenstein, Ludwig. *Wittgenstein's Lectures on the Foundations of Mathematics, Cambridge, 1939. From the Notes of R. G. Bosanquet, Norman Malcolm, Rush Rhees, and Yorick Smythies.* Edited by C. Diamond, Hassocks: Harvester Press, 1976, 300 pp.

In theses lectures from his transitional period Wittgenstein discusses a large variety of topics, based on his notion of rule following. For book length studies on Wittgenstein's philosophy of mathematics see Crispin Wright, *Wittgenstein on the Foundations of Mathematics* (London: Duckworth, 1980, xx + 481 pp.) and S. G. Shanker. *Wittgenstein and the Turning-Point in the Philosophy of Mathematics* (London and Sydney: Croom Helm, 1987, xii + 358 pp.).

4175. Wolters, Gereon. *Basis und Deduktion. Studien zur Entstehung und Bedeutung der Theorie der axiomatischen Methode bei J. H. Lambert (1728–1777).* Berlin/New York: Walter de Gruyter, 1980, xiii + 194 pp.

The author interprets Lambert's philosophy as an early philosophy of science. He focuses on the problem of deduction, especially on Lambert's applications of the mathematical (axiomatic) method to philosophy. Wolters reconstructs Lambert's line calculus and proves it to be a complete diagrammatic calculus of syllogistics.

REGIONAL STUDIES

Under this heading are grouped works that deal with national or regional histories of mathematics that do not fit neatly within the chronological or subject arrangement. As with all the divisions of this bibliography, the ones in this section try to reflect the major areas of research. A number of the items cited can be counted as part of the growing field of ethnomathematics even if they predate its rather recent explicit formation.

One general source is the collection *Human Relations Area Files*. This provides materials relating to about 300 mainly non-Western cultures. Reproductions of pages from published books, articles, and reports, are filed by culture code and then by appropriate subject codes, such as numbers and measures, numeration, games, weights and measures. It is available on microfiche and CD in many libraries.

AFRICA

This bibliography deals with the "sociomathematics" of Africa, mainly in the region south of the Sahara. Emphasis is given to applications of mathematics in the lives of the hundreds of diverse African ethnic groups, and, conversely, the influence of African institutions upon the evolution of their mathematics. Topics include numeration systems and accompanying gesture counting, mystical beliefs involving numbers, monetary systems, time reckoning, weights and measures, record keeping, geometry in art and architecture, and games of strategy and of chance.

There are many more recent works in this area and a good source which keeps up with this literature is the newsletter of the African Mathematical Union's Commission on the History of Mathematics, a group formed in 1986. Issues are also available on the Web at AMUCHMA (http://www.math.buffalo.edu/mad/AMU/amuchma_online.html).

General

4176. Kani, Ahmad, "Arithmetic in the Pre-Colonial Central Sudan", in Gloria Thomas-Emeagwali, ed., *Science and Technology in African History With Case Studies from Nigeria, Sierra Leone, Zimbabwe, and Zambia*. Lewiston: E. Mellen Press, 1992.

4177. Gerdes, Paulus. "On Mathematics in the History of Sub-Saharan Africa." *Historia Mathematica* 21 (1994), no. 3, 345–376.

Presents an overview of research findings and of sources. Topics such as counting and numeration systems, mathematical games and puzzles, geometry, graphs, and continental and international connections are included. Attention is paid to the objectives of research in the history of mathematics in Africa, to methodology, to the relationship with ethnomathematical research, and to the uses of research findings in mathematics education.

4178. Gerdes, Paulus. *Geometry from Africa: Mathematical and Educational Explorations*. Washington, DC: The Mathematical Association of America, 1999.

Presents geometrical ideas from Africa south of the Sahara, with suggestions on how they can be explored both mathematically and in mathematics education. Includes African designs, the discovery of the Pythagorean Theorem, geometrical ideas in crafts, and the 'sona' sand drawing tradition.

4179. Lumpkin, Beatrice. "Africa in the Mainstream of Mathematics History." In *Blacks in Science: Ancient and Modern*. New Brunswick, N.J.: Transaction, 1983, 100–109. Reprinted in *Ethnomathematics. Challenging Eurocentrism in Mathematics Education.* With a foreword by U. D'Ambrosio and an afterword by G. Gilmer. Edited by Arthur B. Powell and Marilyn Frankenstein. (sr SUNY Series, Reform in Mathematics Education). Albany, N.Y.: State University of New York Press, 1997, 101–117.

4180. Raum, O. F. *Arithmetic in Africa*. London: Evans, 1938.

Raised in Tanganyika, Raum used both his own experiences and secondary sources to analyze numeration systems of many African peoples, and to describe applications of arithmetic in the marketplace, in games, in home construction, and other aspects of daily life.

4181. Selin, Helaine. *Encyclopedia of the History of Science, Technology, and Medicine in Non-Western Cultures*. Dordrecht: Kluwer Academic Publishers, 1997, 1117 pp.

Contains articles by the following on the subjects in parenthses: Jacques Sesiano (Abu Kamil; magic squares in Islamic mathematics); Laurance Doyle and Edward Frank (Astronomy in Africa); Jehane Ragai and Gregg de Young (Calendars in Egypt); Ahmed Djebbar (Combinatorics in Islamic mathematics); Jan Hogendijk (Conics); Bala Achi (Construction techniques in Africa); Marcia Ascher (Ethnomathematics); Paulus Gerdes (Geometry in Africa, sona geometry; Mathematics in Africa: south of the Sahara; Numeration systems in Africa); Emilia Calvo (Ibn al-Banna); Roshdi Rashed (Ibn al-Haytham (Alhazen)); Ahmed Djebbar (Ibn Al-Yasamin; Ibn Muncim; the Maghreb; Al-Qalasadi); Yousouf Guergour (Ibn Qunfudhi); Thomas Bassett (Maps and mapmaking); Salimata Doumbia (Mathematics in west Africa: Traditional mathematical games); James Ritter (Mathematics in Egypt); Jens Høyrup (Practical and recreational mathematics); Lawrence Robbins (Namoratunga [archaeoastronomical site]); Gregg de Young (Pyramids); Georges Niangoran-Bouah (Weights and measures in Africa: Akan gold weights); Ruth Willard (Weights and measures in Egypt).

4182. Zaslavsky, Claudia. "Black African Traditional Mathematics". *Mathematics Teacher* 63 (1970), 345–356.

Brief survey of number systems, applications of numbers, and games in several different cultures.

4183. Zaslavsky, Claudia. "Mathematics of the Yoruba People and of Their Neighbors in Southern Nigeria". *The Two-Year College Mathematics Journal* 1 (1970), 76–99.

Yoruba numeration is based upon groupings by twenties. Discusses symbolism of the numbers four and two hundred; the four-day market week, and cowrie shell currency groupings.

4184. Zaslavsky, Claudia. *Africa Counts: Number and Pattern in African Culture*. Boston: Prindle, Weber & Schmidt, 1973; paperback, Westport, Conn.: Lawrence Hill, 1979, 328 pp.

Examines the mathematical contributions of many African peoples living south of the Sahara, in the context of their social and economic development. Using both primary and secondary sources, the author discusses numeration systems, mystical attributes of numbers, applications to time reckoning, currency, and measures, the geometry of African art and architecture, and mathematical games. Includes section by D. W. Crowe on geometric symmetries in African art and artifacts. In-depth studies of southwestern Nigeria and East Africa follow. Photographs, diagrams, tables, maps; 200 references.

Architecture

4185. Denyer, Susan. *African Traditional Architecture*. New York: Africana Publishing Co., 1978.

General survey of architecture and architectural decoration, and their relation to ecological and historic factors. Over 300 illustrations; detailed line drawings of the numerous styles and forms; maps; bibliography.

4186. Garlake, P. S. *Great Zimbabwe*. London: Thames & Hudson, 1973.

Research into the history of the ruins of the "great stone house," the legendary palace and fortified complex of buildings constructed centuries ago in the country now called Zimbabwe. Europeans had attributed this feat of construction to King Solomon or other non-Africans. Discussion of shapes and dimensions of the many buildings and walls.

4187. Oliver, Paul, ed. *Shelter in Africa*. New York: Praeger, 1971.

Detailed articles on the use of space and shape in construction, as well as geometric patterns in house decoration.

4188. Prussin, Labelle. *Architecture in Northern Ghana.* Berkeley and Los Angeles: University of California Press, 1969.

Prussin has done extensive fieldwork in Africa. She stresses the influence of historical and cultural factors in the use of space.

4189. Prussin, Labelle. "Sudanese Architecture and the Manding". *African Arts* 3 (4) (1970), 13–18, 64–67.

Islam introduced new building technology and the square shape to a region that had known only round houses.

4190. Prussin, Labelle. "Fulani-Hausa Architecture". *African Arts* 10 (1) (1976), 8–19, 97 (notes).

Effect of the 1804 Islamic revolution on the use of space in homes and public buildings in the region now known as northern Nigeria and southern Niger.

Art

4191. *African Arts.* Periodical. University of California at Los Angeles, since 1967.

See articles on architecture, patterns in art, and related topics.

4192. Crowe, D. W. "The Geomery of African Art I. Bakuba Art". *Journal of Geometry* 1 (1971), 169–182.

4193. Crowe, D. W. "The Geometry of African Art II. A Catalog of Benin Patterns". *Historia Mathematica* 2 (1975), 253–271.

Group theoretical analysis of repeated patterns, lavishly illustrated by examples from the Bakuba (Zaire) and Benin City (Nigeria).

Games

Mancala is the generic Arabic name of the game played throughout Africa, based entirely on mathematical principles.

4194. Avedon, Elliott M., and B. Sutton-Smith. *The Study of Games.* New York: John Wiley, 1971.

Includes Stewart Culin, "Mancala, the National Game of Africa," originally published by U.S. Government Printing Office in 1894, and other references to this universal African game, as well as to other games of chance and of strategy. African bibliography on pp. 132–135 and 255.

4195. Béart, Charles. *Jeux et jouets de l'Ouest Africain.* Dakar: IFAN, 1955. 2 vols.

Magic squares, mathematical puzzles and riddles, mancala, games of chance, etc.

4196. Bell, R. C. *Board and Table Games from Many Civilizations.* London: Oxford University Press, 1960. 2 vols. Vol. I in paperback.

Versions of mancala and other African games, their origin and history. See also Bell's article on the game of mangola, "Mangola and Mancala Boards", in *Games and Puzzles* 46 (1976).

4197. Centner, T. *L'enfant africain et ses jeux.* Elizabethville, Belgian Congo; Lubumbashi, Zaire: Centre d'Etude des Problèmes Sociaux Indigènes. Collection mémoires 17, 1963.

Networks, counting games, mancala, etc.

4198. Murray, H. J. R. *A History of Board Games Other than Chess.* Oxford: Clarendon Press, 1952.

Most complete collection available. Origins, history, and strategy of mancala and other games going back to ancient Egypt. Hundreds of references, good organization, illustrations, tables.

4199. Nsimbi, M. B. *Omweso, a Game People Play in Uganda.* (Occasional Paper 6.) African Studies Center, University of California at Los Angeles, 1968, 48 pp.

Another version of the universal African game of mancala; history, customs, rules of play, strategy.

4200. Pankhurst, Richard. "Gabata and Related Board-Games of Ethiopia and the Horn of Africa". *Ethiopia Observer* 14 (1971), 154–206.

Well-documented description and history of many versions of mancala.

4201. Russ, Laurence. *Mancala Games.* Algonac, Mich.: Reference Publications, 1984.

Most comprehensive work on the many versions in Africa, as well as in other regions of the world. Illustrations, bibliography.

Markets and Currency

4202. Einzig, Paul. *Primitive Money.* 2nd ed. Oxford: Pergamon Press, 1966.

Part 3 is devoted to Africa. Many references. Deals with such currency items as gold dust in Ghana, cattle in eastern and southern Africa, beads and cloth in various regions.

4203. Johnson, Marion. "The Cowrie Currencies of West Africa". 2 parts. *Journal of African History* 11 (1970), 17–49; 331–353.

Cowrie currency arithmetic, value of cowrie shells from the 14th century to the present, and depreciation of this currency as a factor in the expansion of African numeration systems. Many references.

4204. Kirk-Greene, A. H. M. "The Major Currencies in Nigerian History". *Journal of the Historical Society of Nigeria* 2 (1960), 132–150.

Currencies used in the last five centuries included copper bracelets and bars, beads, cloth, salt, iron bars, and, most popular of all, cowrie shells. Only guns and alcohol maintained stable exchange rates in trade between Europeans and Africans in the 19th century.

4205. Pankhurst, Richard. "'Primitive Money' in Ethiopia". *Journal de la Société des Africanistes* 32 (1962), 213–247.

The use as currency of bars of salt, pieces of cloth, and bars of iron, common in most parts of Africa, is unusually well documented in Ethiopia by historical records covering a period of many centuries. Measures of value used before standardized state currencies.

Numbers and Numeration Systems

4206. Armstrong, Robert G. *Yoruba Numerals.* Ibadan: Oxford University Press, 1962, 36 pp.

History and explanation of the Yoruba numeration system, based on grouping by twenties. The operation of subtraction predominates in constructing the higher numerals.

4207. Brooke, M. "How the Shona Count". *Journal of Recreational Mathematics* 6 (1973), 296–298.

Brief, but provides information on finger counting, names of the days of the week, the months, and basic measurements of the Shona of Zimbabwe.

4208. Delafosse, Maurice. "La numération chez les Nègres". *Africa* 1 (1928), 387–390.

Construction of numeration systems in many languages.

4209. Dieterlen, Germaine. *Essai sur la religion Bambara.* Paris: Presses Universitaires de France, 1951.

Includes discussion of the religious symbolism of numbers among the Bambara of Mali, based on fieldwork.

4210. Ganay, Solange de. "Graphies Bambara des nombres". *Journal de la Société des Africanistes* 20 (1950), 295–305.

Written symbols for numbers developed by the Bambara of Mali.

4211. Monteil, Charles. "Considérations générales sur le nombre et la numération chez les Mandés". *L'Anthropologie* 16 (1905), 485–502.

Number systems of some West African peoples.

4212. Schmidl, Marianne. “Zahl und Zählen in Afrika”. *Mitteilungen der anthropologischen Gesellschaft in Wien* 45 (1915), 165–209.

Extensive discussion of the numbers developed by hundreds of African peoples, based on 260 references; numeration systems, finger gestures, symbolism, and beliefs about numbers, organized by regions.

4213. Seidenberg, A. “The Diffusion of Counting Practices”. *University of California Publications in Mathematics, Vol. 3.* Berkeley and Los Angeles: University of California Press, 1960, 215–299.

Traces the different types of counting systems throughout the world from centers of diffusion. Tables, maps.

Time Reckoning

4214. Nilsson, M. P. *Primitive Time Reckoning.* Lund: C. W. K. Gleerup, 1920.

Discusses societies throughout the world, including African. Calendars based on seasons and on lunar cycles. Market week. Many references.

Weights and Measures

4215. Pankhurst, Richard. “A Preliminary History of Ethiopian Measures, Weights and Values”. *Journal of Ethiopian Studies* 7 (1969), 31–54 and 99–164.

Well-documented research.

4216. Paulme, Denise. “Systèmes pondéraux et monetaires en noire”. *Revue Scientifique* 80 (1942), 219–226.

Arithmetic relationships among weights and measures; currency values.

EAST ASIA

CHINA

Please note that in using this bibliography, various anomalies occur that defy standardization, beginning with the transliteration of Chinese characters which affects both names and titles of works that appear throughout the bibliography. For example, the standard means of transliterating Chinese into the Roman alphabet is Pinyin, but there are other systems as well, including Wade-Giles and a modified version of the latter adopted by Joseph Needham. Taiwan has adopted yet another version of transliteration different from that used in the PRC. This means that the same character can appear in any number of different and not always easily recognizable cognate Romanized forms. For example, the name of Wu Wenchun (item 2312.43) is also spelled as Wu Wen-tsun or Wu Wenjun. Throughout this bibliography names are given as they are spelled in the work under discussion, with the standard Pinyin transliteration given in parentheses when necessary. Thus in the case of Mao Tse-tung (Mao Zedong), Tse-tung is the Wade-Giles spelling of his name, whereas Zedong is the correct Pinyin transliteration.

A similar lack of consistency arises with the many variant translations that have been given for the same Chinese work. Take, for example, the *Zhou bi suan jing* (Wade-Giles: *Chou Pi Suan Ching*), which is usually rendered now as *The Mathematical Classic of the Zhou Gnomon*. Joseph Needham, however, translates this title as *The Arithmetical Classic of the Gnomon and the Circular Path of Heaven*, even though there is no reference at all in the Chinese title to Circular Path of Heaven. Jean-Claude Martzloffs English translator calls the *Zhou Bi* the *Zhou Dynasty Canon of Gnomonic Computations*, but this seems excessively awkward. Nevertheless, despite the vastly different titles in English, these all refer to the same work, the *Zhou bi suan jing*. While in most cases the context or reference to the Pinyin title should minimize any confusion to users of this bibliography, those with little familiarity with Chinese names and titles are warned to proceed with caution.

Similar variants occur in the treatment of words and names transliterated from Russian. Thus A. P. Yushkevich may appear as Iushkevich, Juschkewitsch, Juskevic, and Youschkevitch, among other spellings, although Yushkevich has been adopted as canonical here.

Reference Works and Bibliographies

4217. Ang Tian-Se, and Frank J. Swetz. "A Brief Chronological and Bibliographic Guide to the History of Chinese Mathematics". *Historia Mathematica* 11 (1984), 39-56.

The authors attribute lack of familiarity with history of Chinese mathematics to various factors, including geographical, political, and linguistic problems. Despite language barriers, the authors note "there does exist a rich, albeit dispersed, literature on the history of Chinese mathematics in Western languages." The article begins with a brief "perspective" (pp. 40-43) which discusses the historiography of the subject beginning with the work of Alexander Wylie who wrote about the history of Chinese mathematics in 1852. A chronological outline of the development of Chinese mathematics is provided, followed by a six-page bibliography (pp. 50-56). No commentary or annotations are provided. Both the Wade-Giles and Pinyin transliteration systems are used to romanize the pronunciation of Chinese characters, which are listed in a glossary.

4218. Loewe, Michael. *Early Chinese Texts: A Bibliographical Guide*. Berkeley, CA: The Society for the Study of Early China and The Institute of East Asian Studies, University of California, 1993.

This book surveys ancient Chinese classic texts, and serves as a bibliographic and historiographic guide to studying these works. Each of the experts on the various texts included here has sought to identify which parts of a given work, if any, are suspect or known to be later interpolations; to list the most important traditional and modern commentators; to trace the history of the text through its most important editions and printings; to name the most useful translations into Western languages, together with some of the Japanese editions; and to identify the principal aids to research, including indexes and concordances, relevant to each of the individual texts. Of the 64 early Chinese works included here, two are of special interest to history of Chinese mathematics: The *Chiu chang suan shu* (*Jiu Zhang Suan Shu*) and the *Chou pi suan ching* (*Zhou Bi Suan Jing*). Both of the sections devoted to these works were written by Christopher Cullen. A third work primarily of philosophical interest, but which deals with aspects of logic and mathematics, is the *Mo Tzu* (*Mo Zi*) covered by A. C. Graham.

4219. Martzloff, Jean-Claude. "Chinese Mathematics". In *Companion Encyclopedia of the History and Philosophy of the Mathematical Sciences*. Vol. I. Edited by Ivor Grattan-Guinness. London: Routledge (1994), 93-103.

Discusses sources and evidence for mathematics before the imperial unification of China (221 B.C.), mathematics in the most important of the Chinese classic texts, the *Jiu Zhang Suan Shu* (†Nine Chapters†), related developments in the Han (206 B.C. to A.D. 220), Sui (581-617) and Tang (618-907) dynasties, Late Song and Early Yuan mathematics (13th century), the decline of mathematics in the Ming dynasty (1368-1644), and first contacts with Western mathematics under the Qing (1644-1911). A final section considers "The Westernization of Mathematics in China."

4220. Selin, Helaine, ed. *Encyclopedia of the History of Science, Technology and Medicine in Non-Western Cultures*. Dordrecht: Kluwer, 1997.

This reference work contains nearly 600 entries on the history of science, technology, and medicine outside the United States and Europe, including many devoted to China. It treats broad topics as well as specific subjects, and includes philosophical and biographical articles as well. Written for an undergraduate audience, this encyclopedia offers extensive references; scholars unfamiliar with the subjects treated here will also find this a very useful guide. Illustrations are included where necessary or appropriate.

4221. Yushkevich, Adol'f Pavlovich. "Chinese Mathematics: Some Bibliographic Comments". *Historia Mathematica* 13 (1986), 36-38.

In response to the bibliography published by T. S. Ang and Frank J. Swetz (item 4217), Yushkevich adds 23 titles to the approximately 120 items listed previously from 1835-1982. Yuschkevitch also adds a note to Siu Man-Keung "Pyramid, Pile, and Sum of Squares" in *Historia Mathematica* 8 (1981), 61-66, about the $\sum n$ and $\sum n^2$, noting parallels with Babylonian texts and recent reconstructions of the passages discussed by Siu M. K., S.Ya. Lourie, O. Neugebauer and K. Vogel.

General Surveys

4222. Li Yan, and Du Shiran. *Chinese Mathematics, A Concise History.* Translated by John N. Crossley and Anthony W.-C. Lun. Oxford: Oxford University Press, 1987.

Li Yan (1892-1963) was Du Shiran's supervisor when the latter was a graduate student in Beijing. Du Shiran wrote the original version of this work under his guidance, which was only published after Li's death. In preparing this English translation, Crossley and Lun worked with Du Shiran, who supplied new material which was duly incorporated into the text. The book itself covers the history of mathematics in China from the beginnings before the Qin dynasty (prior to 221 B.C.) down to the introduction of modern Western mathematics to China at the end of the Qing dynasty. It examines the mathematical classics, the outstanding achievements of mathematics made during the Song and Yuan dynasties (960-1368 A.D.), as well as the subsequent introduction of Western mathematics, including Euclid's *Elements*, and indigenous works by Chinese mathematicians in the Ming and Qing dynasties. Appendixes provide useful but brief introductions to the Chinese language, to Chinese books, a chronology of Chinese dynasties, and the basic landmarks of Chinese history. In addition to providing Chinese characters, pinyin pronunciation guides are also given with indications of the proper tone to use for each pinyin transliteration given.

4223. Martzloff, Jean-Claude. *Histoire des mathématiques chinoises.* Paris: Masson, 1987. Revised as †A History of Chinese Mathematics†, translated by Stephen S. Wilson. Berlin: Springer-Verlag, 1997.

This is the most authoritative introduction to the history of Chinese mathematics currently available in any Western language. Originally published in French, the book has been substantially revised, with new material added for the English edition, including new insights, illustrations, and a new appendix on Chinese primary sources as well as a guide to the bibliography on history of Chinese mathematics. The work is comprehensive, and is divided into two parts, the first devoted to the context of Chinese mathematics, the second to its content. Part I covers such matters as historiograhical context, historical context, applications of Chinese mathematics, the structure of Chinese mathematical works, mathematical terminology, different modes of reasoning, transmission of knowledge, influences and transmissions, including possible contacts with the Seleucids and known contacts with Islamic countries, India, Korea, Japan, Mongolia, Tibet, Vietnam, and Europe. Martzloff then turns his attention to Chinese authors and to the main works of Chinese mathematics up to the end of the Qing dynasty. In considering the content of Chinese mathematics, Martzloff focuses primarily on numbers and numeration, calculating instruments, techniques for numerical computation, geometry, indeterminate problems, approximation formulae, Li Shanlan's summation formulae, infinite series, magic squares, and puzzles. Two appendixes are devoted to Chinese adaptations of European mathematical works and to primary sources. In addition to references and an index of Chinese characters, there are three indexes for names, books, and subjects.

4224. Mikami, Yoshio. *The Development of Mathematics in China and Japan*. Leipzig: Teubner, 1913. Reprinted New York: Chelsea, 1974.

The first part of this book, pp. 1-155, is one of the earliest reliable accounts in English of ancient Chinese mathematics. It outlines the main contents of the important Chinese mathematical classics, as well as major contributions of Chinese mathematicians such as Liu Hui, Zu Chongzhi, Qin Jiushao, Yang Hui, Li Ye, and Zhu Shijie. Meanwhile, it also discusses Indian and Arabic influences upon the development of Chinese mathematics. The book occupies an important position in the historiography of ancient Chinese mathematics, and is still a useful reference.

4225. Needham, Joseph, and Wang Ling. *Mathematics and the Sciences of the Heavens and the Earth*. Vol. 3 of *Science and Civilisation in China*. Cambridge: Cambridge University Press, 1959.

Needham's encyclopedic series devoted to the history of Chinese science marks a turning point in the historiography of the subject. It also represents the first serious, extended and scholarly effort, with the help of numerous expert collaborators, to comprehend the entire sweep of science and technology in the course of Chinese civilization. As Needham notes in his preface to volume 3, which includes mathematics, it is meant "to elucidate the contributions of traditional Chinese civilization to mathematics and to the sciences of the heavens and the earth-astronomy and meteorology above, geography and geology below." Only the first part (section 19 of the entire series) is devoted to mathematics (pp. 1-168); the remaining 515 pages are devoted to the sciences of the heavens and of the earth, with approximately another 120 pages devoted to three bibliographies—Chinese books before 1800 A.D., Chinese and Japanese books and journal articles since 1800, and books and journal articles written in Western languages. Another 71 pages constitute the index. In the scope of the 168 pages devoted to mathematics, virtually every major aspect of Chinese mathematics is covered, beginning with an explanation of numeral notation, place-value, and zero. Principal landmarks in Chinese mathematical literature from antiquity to the late Ming period are then presented, after which there follows a description and analysis of specific mathematical topics, including "arithmetica" and combinatorial analysis; logistic of natural numbers; mechanical aids to calculation; artificial numbers (meaning fractions, decimals, surds, and negative numbers); geometry; and algebra. Two final sections take up questions of influences and transmissions, and contrast mathematics and science in China and the West.

Mathematics in Ancient China

4226. Adamo, Marco. "La matematica nel'antica Cina". *Osiris* 15 (1968), 175-195.

This article surveys mathematics in ancient China (prior to the 13th century), giving special emphasis to philosophical and methodological issues.

4227. Berezkina, Èl'vira Ivanovna "Kitaĭ". (†China†.) *Istoriya matematiki s drevneĭshikh vremen do nachala XIX stoletiya.* (†The history of mathematics from ancient times to the early 19th century†.) Vol. 1. Edited by A. P. Yushkevich. Moscow: Nauka, 1970, 156-178.

A chapter on mathematics in China from a three-volume collection, the first of which is devoted to history of mathematics from antiquity to the beginning of the Renaissance. Reviewed in **MR** 58#26719.

4228. Berezkina, Èl'vira Ivanovna "Matematika drevnego Kitaya". (†Mathematics of ancient China†.) In *Proceedings of the 14th International Congress for the History of Science, Tokyo-Kyoto, Japan, 1974.* Tokyo: Science Council of Japan, 1975, 99-102. In Russian.

4229. Berezkina, Èl'vira Ivanovna *Matematika drevnego Kitaya.* (†Mathematics of ancient China†.) Moscow: Nauka, 1980.

This is the first book on history of Chinese mathematics to appear in Russian. It provides a synthesis of several decades of previous study and translations of Chinese texts by the author. After a description of sources, computational techniques are explained. Concepts of number and number-theoretic problems are described, algebra and the solution of equations are discussed, and finally, geometry and applications of algebraic methods to geometry are covered. A bibliography and list of ancient Chinese mathematical signs and terms are included, along with a name but not a subject index. The review by Bruins is critical, especially with respect to the author's interpretation of Babylonian mathematics, the positional decimal system, and Horner-type algorithms. Reviewed by Bruins, E. M. in **MR** 83c:01006.

4230. Berezkina, Èl'vira Ivanovna "Studies in the History of Ancient Chinese Mathematics". *Problems of the Contemporary World* 96 (1981), 162-178.

Gives a brief account of the history of Chinese mathematics in Western countries, emphasizing the former Soviet Union and England. Studies by eminent Chinese historians of mathematics are also mentioned. The major part of the article is devoted to a description of the basic character of ancient Chinese mathematics. The paper also indicates problems and topics that deserve further study.

4231. Berezkina, Èl'vira Ivanovna "The Origin Of Scientific Knowledge In Ancient China". In Russian. In A. N. Shamin, ed. *Ocherki istorii estestvenno-nauchnykh znaniĭ v drevnosti* (†Historical Outlines Of Natural Scientific Knowledge In Antiquity†), Moscow: Nauka, 1982, 178-196.

This work covers the development of astronomy and mathematics in ancient China, from prehistory to the 6th century. Beginning with the decimal place-value system found on Shang dynasty oracle bones (14th century B.C.), the author explains calendars requiring computations of 60-day, 12-day and 10-day cycles. The decimal multiplication table in compact triangular form and the proof that a 3-4-5 triangle is a right triangle, both found in the *Zhou Bi Suan Jing*, are presented. Also discussed is the first exclusively mathematical treatise—the *Jiu Zhang Suan Shu*—"largely a manual for administrators," which includes calculation of areas of fields, volumes of canals, costs of labor, and similar problems. Reviewed by Tee, Garry J. in **MR** 85a:01012.

4232. Chan Hok-Lam. "The 'Distance of a Bowshot': Some Remarks on Measurement in the Altaic World". *Journal of Sung-Yuan Studies* 25 (1995), 29-46.

This essay investigates the use of a bowshot to measure distance or space by Slavic and Altaic peoples, in particular the Mongols under the Genghis and Kublai Khans. Philosophical beliefs, cultural traditions, sociopolitical structures, and even economic conditions are considered. Based on the Mongolian data, the author estimates that a bowshot could range from 300 to 500 meters (p. 37). Although this method is arbitrary and lacks accuracy, it was a product of the life styles and customs of nomadic and semi-nomadic peoples.

4233. Chemla, Karine. "Cas d'adéquation entre noms et réalités mathématiques. Quelques exemples tirés de textes chinois anciens". In *Le Juste nom.* Edited by Karine Chemla and François Martin. (*Extrême-Orient, Extrême-Occident*, 15.) Saint-Denis: Presses Universitaires de Vincennes, Université de Paris VIII, 1993, 102-137.

This paper deals with the way in which names are given to objects in ancient Chinese mathematical texts, and argues that observing the ways in which names are given might help to appreciate the general scholarly prescription that names should adequately relate to the realities they designate. The first example offered relies on a change of names that occurs in the algorithms of root extraction between the beginning of the common era and the 5th century. A statement of the 7th century scholar Li Chunfeng found in his commentary on the *Jiuzhang suanshu*, can be interpreted as referring to this change of name, and as relating it to a basic change in the way of describing the algorithm. His statement seems to diagnose, in terms of the change in terminology, how a name relates to the reality it is supposed to designate. This allows Chemla to analyze which realities are to be named, how the adequacy of names can be determined, etc. Moreover, Li Chunfeng seems to have understood that the names chosen by the authors of the *Jiuzhang suanshu* were indeed adequate to express the realities they designate, which Chemla shows could be related to the fact that one of its authors, Zhang Cang, was a disciple of Xunzi, the main Confucian advocate for the insistence on adequacy between names and realities. The second example deals with the names chosen by Li Ye to designate the segments of the unique drawing on which his *Ceyuan haijing* (1248) is based. The set of names is shown to have a structure similar to the structure consonant with the mathematical context, and it seems that in this case adequacy is to be understood in terms of the terminology as a whole.

4234. Chemla, Karine. "De la signification mathématique de marqueurs de couleurs dans le commentarie de Liu Hui". In *Linguistique et Asie Orientale*. Mélanges en hommage á Alexis Rygaloff. Edited by Alain Peyraube, Irène Tamba, and Alain Lucas. (Cahiers de Linguistique-Asie Orientale, 23.) Pairs: École des Haute Etudes en Sciences Sociales. Centre de recherches linguistiques sur l'Asie Orientale, 1994, 61-76.

Liu Hui (third century), in commenting on the Han classic, *The Nine Chapters on the Art of Mathematics*, uses five colors which appear in two separate sets, each linked more than once with mathematical objects. Following an earlier argument that black and crimson had a specific mathematical meaning for Liu Hui, the author in this paper considers a second set of colors elaborated here, namely yellow, viridian and vermilion, to determine whether they also have a specific mathematical meaning. After showing this to be the case, the author concludes that Liu Hui used color markers to convey mathematical ideas, which raises the question of how ancient Chinese texts should be read. Liu Hui constructs analogies between different situations by using the same color name to mark objects playing similar mathematical roles.

4235. Chemla, Karine. "Qu'est-ce qu'un problème dans la tradition mathématique de la Chine ancienne? Quelques indices glanés dans les commentaires rédigés entre le 3ième et le 7ième siècles au classique Han Les neuf chapitres sur les procédures mathématiques". In *La valeur de l'exemple. Perspective chinoises.* (*Extrême-Orient, Extrême-Occident*, 19.) Saint-Denis: Presses Universitaires de Vincennes, 1997, 91-126.

†The nine chapters on mathematical procedures† (1st century B.C. or A.D.) is composed of problems that are particular in two respects (they involve particular data, and a particular situation in most cases), and of general procedures to solve them. Its commentator Liu Hui (3rd century) reads them as many "examples" to which to conform to solve problems of the same category. By observing the questions for the treatment of which Liu is in need of changing the nature or the data of terms of the classic,

the paper analyses how, in ancient China, mathematical practice put into play the context of problems as such. It is shown that the situation chosen to present a given mathematical problem is used by the commentator as a field of interpretation that the proof of the correctness of the algorithm can put into play to make the meaning of the operations explicit. Moreover the particular data are also put to use in the context of proof, which is shown to relate to specificities of visual auxillaries as used in ancient China.

4236. Chemla, Karine. "Aperçu sur l'histoire des mathématiques en Chine ancienne dans le contexte d'une histoire internationale". In *L'océan indien au carrefour des mathématiques arabes, chinoises, européennes et indiennes, Actes du colloque á Saint-Denis de la Réunion (3-7 novembre 1997).* Edited by D. Tournès Publication de l'IUFM de La Réunion, 1998, 71-90.

A discussion of how history of Chinese mathematics should be written, followed by an outline of the field along the lines considered in the first part.

4237. Cullen, Christopher. "An Eighth Century Chinese Table of Tangents". *Chinese Science* 5 (1982), 1-33.

Cullen discusses the discovery of a listing equivalent to a tangent table based upon gnomon shadows and third-order finite differences. Composed by a Buddhist monk, I-hsing (Yi Xing), his tangent table was apparently derived from Indian sine tables. Yi Xing used his tables in applications to mathematical astronomy; unfortunately, none of his successors seems to have adopted Yi Xing's techniques.

4238. Djamouri, Redouane. "L'emploi des signes numériques dans les inscriptions Shang". In *Sous les nombres, le monde: Matériaux pour l'histoire culturelle du nombre en Chine ancienne.* Edited by Alexeï Volkov. (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 13-42.

4239. Guan' Chzhao-chzhi. (Guan Zhaozhi.) "O matematike v drevnem Kitae". (†On Mathematics in Ancient China†.) *Narodnyĭ Kitaĭ* (*People's China*) 15 (1956), 29-31.

4240. Guo Shi-Rong. "The Role of Mathematics to Agriculture in the Ancient Time". *Journal of the Cultural History of Mathematics* 1 (1992), 37-41.

Taking examples from questions and records related to agriculture in extant Chinese mathematical books, this article examines the role of mathematics in the development of Chinese agriculture.

4241. Kogelschatz, Hermann. "Anmerkungen zur Textgeschichte eines mathematischen Klassikers (Oder: Ein zweiter Fall Dai Zhens?)" *Chinablätter* 9 (1985), 56-66.

4242. Kogelschatz, Hermann. “Liu Huis ’Bogenfeldfigur.’ Eine kritische Auseinandersetzung mit Dai Zhens Rekonstruktion des Hutiantu”. In *Memoriam Achim Hildebrand*. Edited by Achim Mittag. *Chinablätter* 18(1991), 379-396.

4243. Le Xiucheng. “A Comparison of the Structures of the Mathematical Systems of China and the West: Several Revelations from Information Theory”. In *Chinese Studies in the History and Philosophy of Science and Technology*. Edited by Fan Dainian and Robert S. Cohen. Translated by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 255-260.

Dividing mathematical systems into three levels, according to information theory the first constitutes the source of information, the second is the means of obtaining information, and the third is the means of processing information. At all three levels, the author maintains, Chinese and Western mathematics have distinctly different characteristics, which it is the purpose of this article to investigate. Comparisons between microstructures and macrostructures are offered, with a concluding section devoted to “the national character of traditional mathematics.”

4244. Li Di. “On Chinese Ancient Projective Methods from the Drawing of Cart Wheels”. *Journal of the Cultural History of Mathematics* 3 (1993), 2-12.

By examining many representations of cart wheels on drawings and engraved bricks and stones unearthed from the tombs of the Han dynasty, this article argues that ancient Chinese had primitive projective ideas.

4245. Libbrecht, Ulrich. “The Chinese Ta-yen Rule: A Comparative Study”. *Orientalia Lovaniensa* 3 (1972), 179-199.

4246. Lloyd, Geoffrey. “Learning by Numbers”. In *Sous les nombres, le monde: Matériaux pour l’histoire culturelle du nombre en Chine ancienne*. Edited by Alexeï Volkov. (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 153-167.

Lloyd reviews the papers assembled in this issue of *Extrême-Orient, Extrm̂e-Occident* by Redouane Djamouri (item 4238), Karine Chemla (item 4310), Alexeï Volkov (item 4315), Isabelle Robinet, John S. Major, and Hans U. Vogel (item 4254) respectively. Through his comments, the author conveys his opinions about the proper methodology for studying ancient Chinese and Greek sciences in general, and mathematics in particular. Lloyd emphasizes that historians should be primarily interested in the “problems investigated, in the styles of reasoning cultivated, in the relationships between ’mathematics’ (however interpreted) and other types of inquiry, [and] in the roles and value of ’mathematics’ in society,” (p. 153).

4247. Lloyd, Geoffrey. *Adversaries and Authorities: Investigations into Ancient Greek and Chinese Science*. Cambridge: Cambridge University Press, 1996.

This is a wide-ranging exploration of the similarities and differences between ancient Greek and ancient Chinese science and philosophy, concentrating on the period down to A.D. 300. Chapter seven of the book bears the same title as the article published in *Chinese Science* (1996), but with some modifications (140-164).

4248. Needham, Joseph. "Mathematics and Science in China and the West". *Science & Society* 20 (1956), 320-343.

Exactly what were the relations between mathematics and science in ancient and medieval China? Why did the qualitatively new combination of mathematics and science in renaissance Europe, destined to transform the world, happen there and in no other part of the world? After discussing briefly the nature, achievements, and social background of Chinese mathematics (which Needham describes almost entirely in relation to the calendar), two dynasties are presented as most outstanding in their contributions, the Han and Song (p. 325). Needham then discusses the "Origins of the Method of Modern Natural Science in Europe," stressing mathematics and the experimental method. Needham then turns to consider comparisons of Chinese neo-Confucians of the 11th and 12th centuries, and ends with a discussion of "The Social Matrix in Europe and China," whereupon Needham concludes that it was basically the "mercantile culture alone" that did what an "agrarian bureaucratic civilization could not," namely fuse the "formerly separated disciplines of mathematics and nature-knowledge," (p. 343).

4249. Siu Man-Keung. "Mathematics Education in Ancient China: What Lesson Do We Learn From It?" *Historia Scientiarum* 4 (1995), 223-232.

This paper examines mathematics education in China from about 2000 B.C. to about 1600 A.D. The author regards mathematics education in ancient China as a case study and attempts to answer the following questions: What were the main features of mathematics education in ancient China? What were some factors which led to such features? What influence did such features exert upon the development of mathematics in ancient China? And finally, what lessons in mathematics education might be drawn from this study? In the course of this article, the author not only considers specific mathematical works, but also the philosophy of mathematics education in ancient China. The author discusses the examination system and the stress placed in China upon practical applications. He concludes that "too strong [an] inclination towards practical applications, even to the extent of justifying the discipline on applications alone, is unhealthy to its development," (p. 229).

4250. Smith, David Eugene. "Unsettled Questions Concerning the Mathematics of China". *The Scientific Monthly* 33 (September, 1931), 244-250.

This article was written under the influence of certain scholars in China who doubted the authenticity of ancient Chinese texts. Beginning with quotations from Yen Jo-chu (1636-1704), Kang You-wei, and Hu Shih, the author goes on to present his own doubts about some mathematical legends, such as: 1) Fu Xi invented the trigrams; 2) Tai Nao devised a sexagesimal system; 3) Li Shou invented arithmetic. Because of the uncertain dates of some of the classic texts including the *Zhou Bi Suan Jing*, *Jiu Zhang Suan Shu*, and *Sun Zi Suan Jing*, the author is then led to "doubt their antiquity and hope for a more careful study of the texts than has yet been given," (p. 248).

As for the texts written in the 13th and 14th centuries which do bear certain dates, the author criticizes "the obscurity of certain statements in the works," (p. 248). In this light, Smith doubts that Qin Jiu-shao anticipated Horner's method, and conjectures that the mathematical results achieved by Chinese mathematicians in the 13th and 14th centuries were greatly influenced by works of Indians and Arabs. The article ends with a call for further study of the authenticity of ancient Chinese texts in general.

This article conflicts with Smith's previous articles and books on Chinese mathematics; although of little historical value for the history of Chinese mathematics today, its main value now is as a very good reference source for those interested in the history of the history of Chinese mathematics.

4251. Swetz, Frank J. "The 'Piling Up of Squares' in Ancient China". *Mathematics Teacher* 70 (1977), 72-79.

4252. Swetz, Frank J. "The Evolution of Mathematics in Ancient China". *Mathematics Magazine* 52 (1979), 10-19.

This article is divided into three sections. The first, under the heading "Legend and Fact," discusses early legends and Chinese mysticism, focusing on the *Luo Shu*, and questions about the origins of Chinese mathematics. Among topics covered here are the early development of the Chinese place-valued decimal numeral system, as well as mathematical tools such as counting-rods and the counting board. The second section gives a general introduction to such classic texts as the *Zhou Bi Suan Jing* and the *Jiu Zhang Suan Shu*. The Chinese method of extracting square roots and algorithms devised for determining highly accurate numerical values for $\pi$are also mentioned in this section. The last section focuses on Chinese algebraic thought, including indeterminate equations and higher order numerical equations. The article concludes that although "the quality of China's mathematical accomplishments stands in contention with those of Greece and Babylonia, and during the period designated in the West as pre-Renaissance, the sequence and scope of mathematical concepts and techniques originating in China far exceeds that of any other contemporary society," (pp. 17-18). However, in China mathematics never became "an intellectual and aesthetic pursuit," (p. 18).

4253. Vogel, Hans Ulrich. "Aspects of Metrosophy and Metrology during the Han Period". In *Sous les nombres, le monde: Matériaux pour l'histoire culturelle du nombre en Chine ancienne*. Edited by Alexeï Volkov. (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 135-152.

This article first defines the two terms: "Metrology" and "Metrosophy" as "the art of calculation with number, weight and measure units in the economic, fiscal and scientific domains," and "number speculation within cosmological philosophemes," respectively (p. 135). It then goes on to focus on the metrosophical and metrological information contained in the "Lüli" chapter 21A of the *Hanshu* (†Records of the [Western] Han [Dynasty]†), and relationships with contemporary Chinese sciences and cosmology. It also examines possible links between metrology and metrosophy and Chinese political and intellectual conceptions. In conclusion, the article points out that the "Lüli" chapter 21A of the *Hanshu* is "a product of Han correlative thinking which endeavored to systematize, categorize, and integrate phenomena of cosmos, nature, and human realm with the help of ying-yang, Five Phases, and other numerological concepts," (p. 144).

4254. Vogel, Kurt. "Bericht über neuere, in westlichen Sprachen erschienene Arbeiten zur Mathematik der Chinesen". In *Prismata. Festschrift für Willy Hartner*. Edited by Y. Maeyama, and W. G. Saltzer. Franz Steiner, 1977, 423-430.

4255. Van der Waerden, B. L. *Geometry and Algebra in Ancient Civilizations*. Berlin: Springer-Verlag, 1983.

Two sections of this book, namely Part A of Chapter 2 (pp. 36-55), and Part A of Chapter 7 (pp. 192-206), are exclusively devoted to Chinese mathematics. Part A of Chapter 2 is primarily concerned with some algorithms, methods, and problems in the *Jiu Zhang Suan Shu*. Among these are the Euclidean algorithm, volumes of solids, and problems on right-angled triangles. The other section discusses geometry, Liu Hui's measurement of the circle, and his methods of finding the volumes of a pyramid and sphere. In the brief introduction to this book, the author says that he has found many similarities between Chinese and Babylonian mathematics, and this has led him to conjecture that the existence of "a common pre-Babylonian source seemed unavoidable," (p. xi).

4256. Volkov, Alexei [Alexeï; Alekseĭ] Karlovich. "O kharaktere drevnekitaĭskoi matematiki perioda Han'-Tan". (†On the characteristics of Chinese mathematics of the Han-Tang period†.) In *III Vsesoyuznaya shkola molodykh vostokovedov. Tezisy.* (†Third All-[Soviet]-Union Workshop of Young Orientalists. Abstracts†). Vol 1. Moscow: Nauka, 1984, 24-25.

The author argues that traditional Chinese mathematics was not devoted exclusively to the practical needs of everyday life, contrary to the opinion of the majority of modern scholars. He suggests that certain mathematical methods were related to specific religious activities, in particular to designing "ritual" fields of prescribed shape and surface, as well as tombs and other ritual objects.

4257. Volkov, Alexei [Alexeï; Alekseĭ] Karlovich. "O vychislenii ploshchadei v drevnem Kitae". (†On the calculation of areas in ancient China†.) *Istoriko-matematicheskie issledovaniya* (*Studies in history of mathematics*) 29 (1985), 28-43.

The author especially highlights the use of analogical reasoning in demonstrations by Liu Hui (fl. ca. 263) for the calculation of areas found in the *Jiu zhang suan shu* (†Nine Chapters†). Reviewed by Tee, Garry J. in **MR** 87g:01004.

4258. Volkov, Alexei [Alexeï; Alekseĭ] Karlovich. *Matematika v drevnem Kitae III-VII vv.* (†Mathematics in ancient China during 3rd-7th centuries A.D.†). A dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy ("Kandidat Nauk") in Physics and Mathematics. Scientific advisor: A. P. Yushkevich Moscow: Academy of Sciences of USSR, 1988, 323 pp. Unpublished dissertation, defended on May 18, 1989.

A short abstract of the dissertation was published in *Historia Mathematica* 8 (1991), 185–187. The table of contents of the thesis reads as follows: Introduction (p. 6). Chapter 1: Brief outline of the history of Chinese mathematics (second half of the first millennium B.C.-first half of the first millennium A.D.). 1.1. Mathematics of the first millennium B.C.-the first millennium A.D. (p. 34); 1.1.1. Mathematical knowledge in pre-Qin China (p. 34); 1.1.2. Mathematics of the Han epoch (p. 37); 1.1.2.1. Main characteristic features (p. 37); 1.1.2.2. Mathematical treatises (p. 38); 1.1.3. Mathematics of the Three Kingdoms-Northern and Southern dynasties, and the early Tang [dynasty] (p. 39); 1.1.3.1. Main characteristic features (p. 39); 1.1.3.2. Mathematical treatises (p. 42); 1.1.3.3. Mathematical education in the Tang University (p. 44); 1.2. The treatise *Jiu zhang suan shu* (p. 45); 1.2.1. Translation of the title [of the treatise] (p. 45); 1.2.2. The origins of the treatise (p. 51); 1.2.3. The history of the treatise during the Three Kingdoms-Northern and Southern dynasties, and the early Tang [dynasty] (p. 53); 1.2.4. The history of the printed editions of the treatise (p. 56).

Chapter 2. Algebraic and geometrico-algebraic methods. 2.1. The algorithmic character of ancient Chinese mathematical texts (p. 58); 2.2. Extraction of roots and solution of algebraic equations (p. 64); 2.2.1.

Extraction of square roots (p. 65); 2.2.2. Extraction of cube roots (p. 72); 2.2.3. Solution of algebraic equations (p. 76); 2.3. Solution of simultaneous equations (p. 77); 2.3.1. The algorithm of solution of simultaneous equations found in the *Jiu zhang suan shu* (p. 78); 2.3.2. The "new method" by Liu Hui (p. 93).

Chapter 3. Geometrical methods. 3.1. Calculation of areas (p. 98); 3.1.1. The area of a rectangle (p. 99); 3.1.2. The area of a triangle (p. 101); 3.1.3. The area of a trapezium (p. 103); 3.1.4. The area of a circle (p. 106); 3.1.5. The area of a sector (p. 108); 3.1.6. The area of a segment (p. 110); 3.1.7. The area of a ring (p. 114). 3.2. Calculation of volumes (p. 116); 3.2.1. The volume of a parallelepiped (p. 118); 3.2.2. The volume of a triangular prism (p. 118); 3.2.3. The volume of a trapezoidal prism (p. 119); 3.2.4. The volume of a pyramid (p. 120); 3.2.4.1. The volume of a regular quadrilateral pyramid (p. 121); 3.2.4.2. The volume of a "horse"-type pyramid [= yangma] (p. 122); 3.2.4.3. The volume of a "turtle-hand"-type pyramid [= bienao] (p. 136); 3.2.5. The volume of the solid "square pavilion" [= fang ting] (p. 136); 3.2.6. The volume of the solid "hay roof" [= chu meng] (p. 140); 3.2.7. The volume of the solid "hay stack" [= chu tong] (p. 142); 3.2.8. The volume of the solid "stair of sorrow" [= xian chu] (p. 146); 3.2.9. The volume of a cylinder (p. 155); 3.2.10. The volume of a cone (p. 156); 3.2.11. The volume of a cone sector (p. 158); 3.2.12. The volume of a truncated cone (p. 159); 3.2.13. The volume of a sphere (p. 163).

Bibliography [280 entries] (p. 178). Appendices 1. Extraction of square roots (annotated translation) (p. 209); 2. Extraction of cube roots (annotated translation) (p. 221); 3. Solution of simultaneous equations (annotated translation) (p. 229); 4. Calculation of the volume of a pyramid (annotated translation) (p. 242); 5. Calculation of the volume of the solid "stair of sorrow" [=xian chu] (annotated translation) (p. 259); 6. Chinese mathematicians from the end of the first millennium B.C. to the first millennium A.D. (p. 268); 7. Higher education in China (p. 280); 8. Numerical analysis of ancient Chinese standard measuring vessels (p. 286); 9. Structure of ancient Chinese mathematical treatises (the cases of the *Hai dao suan jing* and the *Jiu zhang suan shu*) (p. 300); 10. The methods of demonstration in ancient Chinese mathematics (p. 311).

4259. Volkov, Alexei [Alexeï; Alekseĭ] Karlovich. "Matematika v drevnem Kitae III-VII vv". (†Mathematics in ancient China during 3rd-7th centuries A.D.†) Moscow: Academy of Sciences of USSR, 1989, 27 pp.

Abstract of the PhD dissertation (item 4258).

4260. Volkov, Alexeï[Karlovich]. "Recherches sur les structures des textes chinois anciens en URSS". In *Modèles et structures des textes chinois anciens.* Edited by Karine Chemla, Viéra V. Lichtmann, and

Alexeï Volkov. (*Extrême-Orient, Extrême-Occident*, 13.) Saint-Denis: Presses Universitaires de Vincennes, 1991, 11-30.

The author introduces a collection of papers edited and translated from Russian, by recounting the historical development in the former Soviet Union of a trend of formalist approaches to ancient Chinese texts. The idea that ancient Chinese texts might have been composed on the basis of formal patterns and that their interpretation demanded that these patterns be brought to light was first proposed by Spirin and later developed by other scholars as well. Based on a large bibliography, the article describes the main contributions of each author.

4261. Volkov, Alexei Karlovich. "Transformation of Objects in Ancient Chinese Mathematics And Their Evolution". In *Notions et perceptions du changement en Chine*. (Mémoires de l'Institut des Hautes Etudes Chinoises, 36.) Edited by Viviane Alleton and Alexeï Volkov. Paris: Collège de France, 1994, 133-148.

This paper aims at reconstructing the "conceptual shifts" in the history of methods for calculating areas and volumes in Chinese mathematics. The main source for this reconstruction is the mathematical classic, *Jiu zhang suan shu* (ca. first century A.D.), along with the commentaries on this text written by Liu Hui (fl. ca. 263). The extant version of the treatise, edited by Li Chunfeng (602-670), also contains fragments of commentaries attributed to other mathematicians, in particular to Zu Geng (the late 5th-early 6th century). The first conceptual shift in methodology can be described as a transfer from strategies of simple recombination of parts of simple rectilinear figures (transforming them into rectangles or upright boxes) to methods for calculating areas and volumes of curvilinear figures using infinitesimal iterative procedures, including evaluations of both upper and lower boundaries of the value sought.

The second conceptual shift is related to the introduction of a more advanced class of methods for calculating volumes of solid figures with round sections (due to Liu Hui) as well as for solid figures with sections belonging to an even wider class of shapes (due to Zu Geng). In works on the history of Chinese mathematics, the latter procedures have often been described as based on a method similar to Cavalieri's principle. The author argues instead that these methods were obtained through transfers inspired by logical analogy with simpler cases.

4262. Wu Wen-tsun (Wu Wenjun; Wu Wenchun). "Recent Studies of the History of Chinese Mathematics". In *Proceedings of the International Congress of Mathematicians.* Berkeley, California, 1986, 1657-1667.

This article begins with the statement of two basic principles for studying ancient Chinese mathematics, i.e. "All conclusions drawn should be based on original texts fortunately preserved up to the present time," and "All conclusions drawn should be based on reasoning in the manner of our ancestors in making use of knowledge and in utilizing auxiliary tools and methods available only at that ancient time," (p. 1657).

Section two considers ancient Chinese theoretical studies involving integers, for instance, triples of integers and the Chinese Remainder Theorem (although the author points out that the concept of prime number was not introduced). Section three focuses on Chinese geometry which was not approached in the Euclidean fashion of a deductive system, but rather in terms of "a few general plausible principles on which various geometrical results were then discovered and proved in a deductive manner," (p. 1661). Three of these principles have been generalized as 1) Liu Hui's Principle (on *Yangma* and *Bienao*); 2) "Out-In Complementary Principle"; and 3) Liu-Zu's Principle (Cavalieri's Principle in the West). The last section of this paper is devoted to algebra, "the most developed part of mathematics in ancient China," (p. 1665). Here Chinese methods for solving linear equations are considered, including the *Tian-Yuan* method for finding unknowns, and the *Si-Yuan* method (four unknowns), among others. In conclusion, the author writes that "Chinese ancient mathematics was mainly constructive, algorithmic, and mechanical in character," (p. 1666).

4263. Wu Wen-tsun (Wu Wenjun; Wu Wenchun). "The Out-In Complementary Principle". In *Ancient China's Technology and Science.* Beijing: Foreign Languages Press, 1983, 66-89.

The out-in complementary principle was widely applied throughout all ancient Chinese mathematics. Basically, it assumed that if a planar figure is cut into several sections, the sum of the areas of the sections would be equal to the area of the original figure. This principle was used to show, for example, that the area of any triangle is equal to half the product of one side and the associated altitude. This basic idea was applied to a number of different situations, including applications to problems involving the gnomon, shadow, and double differences. It could be used to prove, for example, the Gougu theorem (the so-called Pythagorean theorem in the West). Wu also considers methods for determining one of the lengths from two of the others; various formulas for finding the areas of figures as discussed in Qin Jiushao's *Shu Shu Jiu Zhang* (†Mathematical Treatise in Nine Sections†; 1247) are also given ; extracting square or cubic roots is covered, as is solution of quadratic equations, the theory of volumes, Liu Hui's principle, determination of the volume of the sphere, and other applications, all of which prompt the author to conclude that "the principles of Liu Hui and Zu Geng demonstrated the considerable abilities of ancient Chinese masters in scientific abstraction."

4264. Yushkevich, Adol'f Pavlovich. "O dostizheniyakh kitaĭskikh uchenykh v oblasti matematiki". (†On the achievements of Chinese scholars in the field of mathematics†.) *Istoriko-matematicheskie issledovaniya* (*Studies in history of mathematics*) 8 (1955), 539-572. Reprinted in I. V. Kuznetsov et al., eds., *Iz istorii nauki i tekhniki Kitaya* (†On the History of Science and Technology in China†). Moscow: Academy of Sciences, 1955, 130-159.

The author begins with the *Jiu zhang suan shu* (the title is rendered as †Mathematics in nine sections†) and provides a detailed description of the method of solution of simultaneous linear equations. Yushkevich remarks that the uniform algorithm, found in the treatise, was developed in Europe much later, in the 17th century, by Leibniz. He also mentions the introduction of "positive" and "negative" "magnitudes" in the context of the algorithm, yet he remarks that there is not enough evidence to suggest what the correct interpretation of "negative magnitudes" should be; he suggests that in a certain context a "negative magnitude" can be understood as a deficit or debt. The author goes on to discuss the "so-called Pythagoras theorem" and analyses problems 13 and 20 from chapter 9 of the treatise. He discusses methods for solving equations of second and higher degrees. He remarks that the general formula for quadratic equations is not found in the treatise, yet claims that all the successive steps leading to it were known to the ancient author(s) of the treatise. To support his hypothesis, he provides a discussion of problem 11, chapter 9 of the treatise, as well as the commentaries of Yang Hui (1261) on the method. Yushkevich also mentions the method of solution of quadratic equations based on the binomial expansion, yet he attributes it to Liu Yi (ca. 1080); he poses as open the question of whether the same method was known to the author(s) of the *Jiu zhang suan shu*. He remarks that the ancient method was soon generalized: as early as in the first millennium A.D. a cubic equation was solved by Wang Xiaotong (7th century A.D.), and in the 13th and 14th centuries the method was applied to equations of higher degree (the author provides an example from the *Shu shu jiu zhang* by Qin Jiushao). He compares the method with its later equivalent found in the works of al-Kashi (1427), Viète (1600), Ruffini (1804, 1813), and Horner (1819). The author also mentions Zhu Shijie's (ca. 1300) solution of simultaneous equations of higher degree with four unknowns. He discusses the indeterminate analysis (pp. 144-145), summation of finite series by several medieval Chinese mathematicians (pp. 145-149), approximate values of π calculated by Liu Hui (fl. ca. 263) and Zu Chongzhi (429-500) (pp. 149-151), and problem 2 from the *Hai dao suan jing* by Liu Hui (pp. 151-152). In his concluding discussion (pp. 152-158) the author objects to the established (by the time when the paper was written) image of Chinese mathematics as of a "dogmatic" and "empirical" discipline. He highly evaluates the development of the algorithms within several "eastern" mathematical traditions, and stresses the role of scientific contacts between the scholars of medieval Central Asia, India and China. The bibliography (22 entries) includes the works of Li Yan, Qian Baozong, Xu Chunfang, Du Shiran, partly translated into Russian, and E. Berezkina (unpublished manuscripts).

4265. Yushkevich, Adol'f Pavlovich. "Issledovaniya po istorii matematiki v drevnem Kitae". (†Studies in the history of mathematics in ancient China†.) *Voprosy Istorii Estestvoznaniya i Tekhniki* (*Problems of the History of Natural Science and Technology*) 3 (1982), 125-136.

Reviewed in **MR** 87e:01005.

4266. Yushkevich, Adol'f Pavlovich. "O matematike drevnego Vostoka i drevneĭ Gretsii". (†On the mathematics of the ancient East and ancient Greece†.) In *Metodologicheskie problemy razvitiya i primeneniya matematiki*. (†Methodological problems of the development and application of mathematics†.) Moscow: USSR Academy of Sciences Press, 1985, 168-173.

4267. Zinin, Sergeĭ Vasil'evich. "Nekotorye problemy kitaĭskoĭ aritmologii". (†Some problems of Chinese arithmology†.) In *16-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov*. (†16th Scientific Conference "Society and State in China." Abstracts of papers†.) Vol. 1. Moscow: Nauka, 1985, 151-155.

This paper contains a short discussion of the treatise *Shu shu ji yi* (†Memoir on the methods of numbering†) written by Xu Yue (fl. ca. A.D. 220). The author claims that the treatise was primarily devoted to "numerology" (a word which was understood in Soviet sinology in the early 1980s as referring to the phenomenon of the overwhelming use of number symbolism in ancient and medieval Chinese culture) or "arithmology." The author suggests that "arithmological" "numbers" were distinct from "number-magnitudes"; the former were intrinsically related to geometrical images. The appendix (pp. 153-155) contains a full Russian translation of the treatise, but without annotations and without a translation of the voluminous commentaries by Zhen Luan (fl. ca. 570).

4268. Zinin, Sergeĭ Vasil'evich. "Pozdnekhan'skaya kosmologicheskaya skhematika". (†Cosmological schemes of the Later Han dynasty†.) In *Istoriya i kul'tura Vostochnoĭ i Yugo-vostochnoĭ Azii*. (†History and Culture of East and South East Asia†.) Vol. 1. Edited by S. V. Volkov. Moscow: Nauka, 1986, 84-93.

This paper provides a further discussion on the *Shu shu ji yi* by Xu Yue (fl. ca. 220) and the commentary by Zhen Luan (fl. ca. 570). The author claims that the treatise has strong connections with Daoist alchemy; as he puts it, the treatise is an alchemical text disguised as a numerological treatise. One of the key figures of the treatise, the Master [from the] Mountain of Celestial Eyes, is identified by the author as Zhang Daoling (fl. the second century A.D.), the patriarch of the Daoist sect of Celestial Masters (here the author is most probably following a short remark in the third volume of *Science and Civilisation in China* (item 4225)). The second part of the paper is an annotated translation of the description of 14 "methods of numbering" from the commentary of Zhen Luan which includes descriptions of several counting devices, one of which has been identified by modern scholarship as the earliest Chinese abacus.

On the Ten Classics

4269. Du Shiran. "Mathematical Classics". In *Ancient China's Technology and Science*. Beijing: Foreign Languages Press, 1983, 50-56.

Here Du Shiran discusses the traditional "Ten Classics" of Ancient Chinese mathematics, the first printed versions from the Southern Song editions (1127-1279) as well as mathematical works in the Song and Yuan Dynasties (960-1368). At least for this period, the author expresses amazement "at the extent to which Chinese mathematics led the West," especially in the solution of higher numerical equations and of multivariate higher simultaneous equations using finite differences comparable to later works by Horner, Bezout, and Newton.

4270. Kogelschatz, Hermann. *Bibliographische Daten zum frühen mathematischen Schrifttum Chinas im Umfeld der 'Zehn mathematischen Klassiker' (1. Jh. v. Chr. bis 7. Jh. n. Chr.)* Munich: Veröffentlichungen des Forschungsinstituts des Deutschen Museums für die Geschichte der Naturwissenschaften und der Technik, Reihe B., 1981.

This book is arranged as an index, guiding the reader to the main topics of the history of the *Suanjing shishu* (†Ten classics of mathematics†), including editors and critical editions.

4271. Schrimpf, Robert. *La collection mathématique "Souan King Che Chou." Contribution á l'histoire des mathématiques chinoises des origines au VIIe siècle de notre ère*. Thèse soutenue á l'Université de Rennes, 1963. 3 vols.

This thesis was the first one in the West to be devoted to the collection assembled in 656 and known as *Suanjing shishu* (†Ten classics in mathematics†). After a brief introduction sketching the history of mathematics in China, the author describes the circumstances in which each of the ten mathematical classics was composed and how they came down to us. In addition to this, he lists all the commentaries which were written down to Qing times on this subject. The main part of the thesis consists of an analysis of the mathematical content of the *Suanjing shishu*: first a description of the form of each treatise, followed by an analysis of the arithmetical part (numbers and computations; fractions; root extractions; rule of three; rule of double false position), the geometrical part (surfaces such as triangles and right-angled triangles, quadrilaterals, circles, annuli; volumes such as the cube, the parallelepiped, the pyramid, the cylinder, the sphere), and the algebraic part (linear problems, quadratic and cubic equations; indeterminate problems). Among several appendices, one translates the terms of all problems that appear in the collection.

On Individual Classics

4272. Ang Tian-Se. *A Study of the Mathematical Manual of Chang Ch'iu-chien*. Kuala Lumpur: University of Malaya, 1969; unpublished M.A. Thesis.

4273. Ang Tian-Se, and F. J. Swetz. "A Chinese Mathematical Classic of the Third Century: The Sea Island Manual of Liu Hui". *Historia Mathematica* 13 (1986), 99-117.

Written by the Chinese mathematician Liu Hui (fl. ca. 263 A.D.), this Chinese classic (*Haidao suanjing*) presents nine surveying problems whose solutions involve properties of right triangles used to determine distances to inaccessible points. According to the authors, "Liu's results were obtained through the use of a prototrigonometry based on the concept of chong cha [double differences]." This article offers a translation of Liu Hui's work, and discusses the significance of this early Chinese mathematical text.

4274. Berezkina, È l'vira Ivanovna, (Berëzkina, Beryozkina) translator. "Matematika v devyati knigakh". (†Mathematics in nine books [= *Jiu zhang suan shu*]†.) *Istoriko-matematicheskie issledovaniya* (*Studies in the history of mathematics*) 10 (1957), 427-584.

This is the first annotated translation of the *Jiu zhang suan shu* (ca. early 1st century A.D.) published in a modern (European) language. The translator did not include in her translation the commentaries of either Liu Hui (ca. A.D. 263) or Li Chunfeng (602-670) which traditionally accompany the treatise in all extant editions. Berezkina's publication contains: "Predislovie k russkomu izdaniyu Matematiki v devyati knigakh" (Foreword to the Russian edition of the Mathematics in Nine Books) by Hua Luogeng, pp. 425-426; and the following items by E. I. Berezkina "O Matematike v devyati knigakh" (On the Mathematics in Nine Books) pp. 427-438; "Matematika v devyati knigah" (Mathematics in Nine Books) pp. 439-513; "Primechaniya k Matematike v devyati knigakh" (Annotations to the Mathematics in Nine Books) pp. 514-584.

4275. Berezkina, È l'vira Ivanovna, (Berëzkina, Beryozkina). "Arifmeticheskie voprosy v drevnekitaĭskom traktate 'Matematika v 9 knigakh'". (†Arithmetic problems in the ancient Chinese treatise †Mathematics in nine books† [= *Jiu zhang suan shu*]†.) In *Iz istorii nauki i tekhniki v stranakh Vostoka*. (†From the history of science and technology in the countries of the East†.) Vol. 1. Moscow: Nauka, 1960, 34-55.

In addition to proportions and sequences, the Chinese numeral system and basic arithmetic operations with whole numbers and fractions are studied here, especially methods for calculating with counting rods. That these coincide with methods also found in India is, according to Vogel, "offensichtlich" (obvious). Reviewed by Vogel, K. in **MR** 40#4053.

4276. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "O matematicheskom traktate Sun'-tszy". (†On the mathematical treatise of Sunzi†.) *Istoriko-matematicheskie issledovaniya* (*Studies in the history of mathematics*) 13 (1961), 219-230.

This paper discusses an arithmetic treatise, including tables, which provide a tabulation of mn^2 and m^2n^2 for $m, n = 1, 2, \ldots 9$. There is a full description of how the counting board is used and two systems the Chinese used for designating high powers of 10. Books 2 and 3 of the *Sunzi Suan Jing* (†The Mathematical Classic of Sunzi†) consist of 64 examples, worked out, involving proportions, percentages, progressions, metrology, areas of fields, square roots, systems of linear equations, linear indeterminate equations, etc. Reviewed by Kennedy, E. S. in **MR** 25#4.

4277. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "O matematicheskom trude Sun'-tszy. Sun'-tszy: *matematicheskiĭ traktat*. Primechaniya k traktatu Sun'-tszy". (†On the mathematical work of Sunzi. Sunzi: *Mathematical treatise*. Notes on Sunzi's treatise†.) In *Iz istorii nauki i tekhniki v stranakh Vostoka* (†From the history of science and technology in the countries of the East†.) Vol. 3. (Moscow: Nauka), 1963, 5-70.

The first complete annotated translation of the *Sunzi suan jing* into a European language. The extensive review of this work [by K. Vogel in **MR** 40#4054-6] covers Berezkina's introduction to the translation, the contents of the treatise itself, with notes which include analysis of the exercises in this classic text. Errors are pointed out and much that is otherwise obscure is explained. Especially useful is the description of how procedures for calculating on the counting board were actually carried out. "Thus one sees clearly how the processes of multiplication, division, and extraction of roots correspond directly to the later methods of the Indians, Arabs, and [practitioners in the] Latin West."

4278. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "Ob odnom drevnekitaĭskom matematicheskom traktate". (†On an ancient Chinese mathematical treatise†.) *Istoriko-matematicheskie issledovaniya* (*Studies in the history of mathematics*) 17 (1966), 261-271.

The author shows how the *Wu Cao Suan Jing*, overlooked by Chinese mathematicians and modern historians of mathematics alike, is worth studying. Designed for practitioners, it not only introduces new technical terms, but employs previously unknown monetary systems and uses decimal fractions applied to numerous practical problems, including wages and taxes; approximation formulas for areas and volumes of various irregular figures are also calculated Reviewed by Vogel, K. in **MR** 35#2701.

4279. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "O traktate Chzhan Tsyu-tszyanya po matematike. Matematicheskiĭ traktat Chzhan Tsyu-tszyanya". (†On the mathematical treatise of Zhang Qiujian. Mathematical treatise of Zhang Qiujian.†) In A. T. Grigor'yan and A. P. Yushkevich, eds., *Fiziko-matematicheskie nauki v stranakh Vostoka*. (†Physics and mathematics in the countries of the East†). Vol. 5. (New series: issue 2) Moscow: Nauka, 1969, 18-81.

The first complete annotated translation of the *Zhang Qiujian suan jing* into a European language. This work was meant as a study aid for promotion to the "first rank" of the state service. Divided into three parts, 92 problems are presented on diverse topics, including geometry, arithmetic, examples involving fractions and progressions, and algebraic problems involving first and second degree equations; answers and methods of solution are also provided, including the commentary by Li Ch'iu-fen (Li Chunfeng) in the 7th century. Reviewed by Veselovskiĭ, I. N. in **MR** 41#8a-c.

4280. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "O matematicheskom traktate pyati vedomstv. *Matematicheskiĭ traktat pyati vedomstv*. Primechaniya k vedomstvennomu traktatu". (†On the mathematical treatise on five departments. †The mathematical treatise on five departments [= Wu cao suan jing]. Annotations to the treatise on departments.††) In *Fiziko-matematicheskie nauki v stranakh Vostoka*. (†Physics and mathematics in the countries of the East†.) Vol. 2. Moscow: Nauka, 1969, 82-97.

The first complete annotated translation of the *Wu cao suan jing* into a European language. This rudimentary treatise (ca. 4th century A.D.) covers "Agrarian Department," "Military Department," "Commercial Department," "Financial Department," and "The Customs Department." The mathematical level is basic, intended for practitioners, and does not go beyond simple arithmetic problems, including the rule of three and basic mensuration. Reviewed by Veselovskiĭ, I. N. in **MR** 40#5388a-c.

4281. Berezkina, Èl'vira Ivanovna, (Berëzkina, Beryozkina). "Dva teksta Lyu Khuèya po geometrii. *Matematicheskiĭ traktat o morskom ostrove. Matematicheskiĭ traktat o morskom ostrove* Lyu Khueya. Dve zadachi iz *Matematiki v devyati knigakh* i kommentarii k nim s vychisleniem chisla π. Primechaniya k vychisleniyu Lyu Khuèem chisla π. K istorii chisla π v Drevnem Kitae". ("Two texts on geometry by Liu Hui. †Mathematical treatise on sea island† [= *Hai dao suan jing*, a Russian translation]. †Mathematical treatise on sea island† by Liu Hui. †Two problems from the *Mathematics in nine books*† [= *Jiu zhang suan shu*] and the commentary on them by Liu Hui containing the calculation of the number π. On the history of π in ancient China".)

Istoriko-matematicheskie issledovaniya (*Studies in the history of mathematics*) 19 (1974), 231-273.

An annotated complete translation of the *Hai dao suan jing* by Liu Hui (fl. ca. 263), and of an excerpt from Liu Hui's commentary on the *Jiu zhang suan shu* devoted to the calculation of the area of a circle and an approximate value of π (chapter 1, problems 31-32). Reviewed in **MR** 57#12020.

4282. Berezkina, È̀l'vira Ivanovna, (Berëzkina, Beryozkina). "Matematicheskiĭ traktat Syakhou Yana". (†Mathematical treatise of Xiahou Yang†.) *Istoriko-matematicheskie issledovaniya* (*Studies in history of mathematics*) 28 (1985), 293-337.

The first complete annotated translation of the *Xiahou Yang suan jing* into a European language. In three books, rules and 82 problems are presented. Among topics covered are basic arithmetic operations; measures of length, capacity and weight; calculation of areas and volumes of irregular figures; the rule of three and proportions; interest and percentages. A detailed introduction and commentaries accompany the text. Reviewed by Volodarski, A. I. in **MR** 87h:01008.

4283. Berezkina, È̀l'vira Ivanovna, (Berëzkina, Beryozkina). "Van Syao-tun. Matematicheskiĭ traktat o prodolzhenii drevnikh [metodov]". (†Wang Xiaotong. Mathematical treatise on the continuation of ancient [methods]†.) *Istoriko-matematicheskie issledovaniya* (*Studies in the history of mathematics*) 20 (1975), 329-371.

The first complete annotated translation of the *Qi gu suan jing* into a European language. This work by Wang Xiaotong (7th century A.D.) concerns equations of degree three and four. "The medieval author solved problems for cubic equations using a numerical method which is the same as Horner's method." Reviewed in **MR** 58#21039a-b, (author's summary).

4284. Chemla, Karine. "Relations between procedure and demonstration. Measuring the circle in the *Nine Chapters on Mathematical Procedures* and the commentary by Liu Hui (3rd century)". In H. N. Jahnke, N. Knoche, and M. Otte, eds., *History of Mathematics and Education: Ideas and Experiences*. Göttingen: Vandenhoeck and Ruprecht, 1996, 69-112.

This article is devoted to an analysis of the commentary which Liu Hui (Wei-Jin period) wrote on the procedure to compute the area of a circle given in the Han classic, *The Nine Chapters on the Art of Mathematics*. It discusses philological issues connected with the interpretation of the text. Moreover, it attempts to elucidate the way in which Liu Hui faces the infinite number of steps needed to account for the procedure he uses, in contrast with pre-Eudoxean and Eudoxean texts devoted to similar topics. Emphasis is placed on the relationship between procedure and proof: how does Liu Hui's proof relate to the procedure stated in the classic text? How does the algorithm given later to compute a more accurate value for pi relate to the proof? This leads the author to define two kinds of operations that can intervene in a procedure: the first kind involves abstract operations, executed only at the semantic level; the second kind involves numerical operations. This distinction makes it possible to describe the relationship between proofs and algorithms in a more accurate way, and is shown to relate to the difference between concepts such as *mi* (surface/area) and *ji* (product/surface).

4285. Chemla, Karine. "History of Mathematics in China: A Factor in World History and a Source for New Questions". In *Proceedings of the International Congress of Mathematicians, Berlin, 17-27 août 1998. Documenta Mathematica, Journal der Deutschen Mathematiker-Vereinigun, Extra-Volume ICM 1998.* Vol. III. *Invited Lectures.* 789-98.

This paper summarizes some recent results concerning the Han classic, *The Nine Chapters on Mathematical Procedures* and the commentaries on it ascribed to Liu Hui (3rd century) and Li Chunfeng (7th century). It describes some basic algorithms contained in *The Nine Chapters* and points to features of the proofs of their correctness given by the commentators. It highlights some specificities of the mathematical results contained in these texts and of the mathematical practice to which they bear witness. Moreover, it presents results concerning their transmission westwards.

4286. Cullen, Christopher. *Astronomy and Mathematics in Ancient China: the Zhou Bi Suan Jing.* Cambridge, England: Cambridge University Press, 1996.

This is the first full-length translation and scholarly study in English of the earliest Chinese classic text on astronomy and mathematics, which dates from the first century A.D. The author discusses the background of the *Zhou Bi*, its origins, contents, and later history, including commentaries on this work by Zhao Shuang (Zhao Junqing), Zhen Luan, and Li Chunfeng's later edition of the work as part of the canon of ten mathematical classics. Careful attention is paid to explaining the technical details of Chinese calendrical astronomy, as well as the mathematics that supported it. Aspects of cosmography, instrumentation, and observation are also covered. Four appendixes discuss Zhao Shuang and the so-called "Pythagorean" theorem, the problem of determining the height of the sun, the diagram of the seven *heng* [orbits of the sun], and the old shadow table upon which Zhao Shuang based a new construction presented in the *Zhou Bi.*

4287. Dauben, Joseph W. "The 'Pythagorean Theorem' and Chinese Mathematics: Liu Hui's Commentary on the *Gou-Gu* Theorem in Chapter Nine of the *Jiu Jang [=Zhang] Suan Shu*". In *Amphora:*

Festschrift in Honor of Hans Wussing. Leipzig: B. G. Teubner, 1992, 133-155.

This article provides a preliminary and relatively brief, exploratory discussion of the nature of early Chinese mathematics, especially geometry, considered largely in terms of one specific example: *Gou-Gu* Theorem. In addition to drawing some fundamental comparisons with Western traditions, especially with Greek mathematics, some general observations are also made concerning the character and development of early Chinese thought. Above all, why did Chinese mathematics develop as it did, as far as it did, but never in the abstract, axiomatic way that it did in Greece? Many scholars have suggested that answers to these kinds of questions are to be found in social and cultural factors in China. Some favor the sociological approach, emphasizing for example that Chinese mathematicians were by nature primarily concerned with practical problems and their solutions, and therefore had no interest in developing a highly theoretical mathematics. Others have stressed philosophical factors, taking another widely-held view that Confucianism placed no value on theoretical knowledge, which in turn worked against the development of abstract mathematics of the Greek sort. While both of these views contain elements of truth, and certainly play a role in understanding why the Chinese did not develop a more abstract, deductive sort of mathematics along Greek lines, a different approach is offered here. To the extent that knowledge is transmitted and recorded in language, oral and written, logical and linguistic factors cannot help but have played a part in accounting for how the Chinese were able to conceptualize—and think about—mathematics.

4288. Gillon, Brendan S. "Introduction, Translation, and Discussion of Chao Chün-Ch'ing's 'Notes to the Diagrams of Short Legs and Long Legs and of Squares and Circles'". *Historia Mathematica* 4 (1977), 253-293.

One of the earliest lengthy discussions of the properties of the right triangle, the so-called "Pythagorean theorem," in ancient Chinese mathematics appears in the commentary on the *Zhou Bi suan jing* by Chao Chün-Ch'ing (Zhao Junqing, also known as Zhao Shuang). Active in the Wei-Jin periods (3rd and 4th centuries A.D.), Zhao Shuang wrote an †Illustrated Commentary on the Right Triangle, Circle, and Square† which is translated here, with notes and lengthy discussion of the mathematical details involved.

4289. L. van Hée, tr. "*Le Classique de l'île Maritime*, Ouvrage chinois du IIIe Siècle". *Quellen und Studien zur Geschichte der Mathematik* 2 (1933), 255-280.

French translation of Liu Hui's classic text, the *Hai Dao Suan Jing* (†Sea Island Mathematical Manual†).

4290. Ho Peng-Yoke. "The Lost Problem of the *Chang Ch'iu-chien Suan Ching*, a Fifth-Century Chinese Mathematical Manual". *Oriens Extremus* 12 (1965), 37-53.

The extant versions of the *Chang Ch'iu-chien Suan Ching* [*Zhang Qiujiang suanjing*] are incomplete. Missing portions occur between the end of the second chapter and the beginning of the third chapter. This article discusses missing parts of the text.

4291. Lam Lay Yong. "Yang Hui's commentary on the '*ying nu*' chapter of the *Chiu Chang Suan Shu*. *Historia Mathematica* 1 (1974), 54-55. "

In 1261 the mathematician Yang Hui wrote two important works on the ancient classic text, the *Nine Chapters* (*Jiu Zhang Suan Shu*); these were his *Xiangjie jiuzhang suan fa* (†A Detailed Analysis of the Mathematical Methods in the Nine Chapters†) and his *Jiuzhang suanfa zuan lei* (†Reclassification of the Mathematical Methods in the "Nine Chapters"†). Chapter seven of the *Nine Chapters* is called "*Ying bu zu*" ("Excess and Deficiency"), and uses what European mathematicians called the rule of false position. Yang Hui made a detailed and thorough study of the twenty problems in this chapter of the *Nine Chapters*, and sought to explain and expand its method while suggesting as well alternative and simpler solutions for some of the problems. This paper translates the 20 problems, analyzes the "*Ying bu zu*" method, and presents a critical study of Yang Hui's alternative methods.

4292. Lam Lay Yong. "*Jiu Zhang Suanshu* (†Nine Chapters on the Mathematical Art†): An Overview". *Archive for History of Exact Sciences* 47 (1994), 1-51.

This paper provides a detailed overview of the *Jiu Zhang Suan Shu*. After discussing the general introduction to the book, relatively detailed descriptions follow of each of the nine chapters, topic by topic. In each case some typical problems are presented and discussed, along with Liu Hui's commentaries, which are also rendered into English. A general analysis of the book is also provided.

4293. Lam Lay Yong. "*Zhang Qiujian Suanjing* (†The Mathematical Classic of Zhang Qiujian†): An Overview". *Archive for History of Exact Sciences* 50 (1997), 201-240.

This is a through study of the *Zhang Qiu Jian Suan Jing*. After a detailed consideration of the preface to the book, three chapters provide an English translation of Zhang's work, followed by an evaluation of the place of the *Zhang Qiu Jian Suan Jing* in the history of mathematics.

4294. Lam Lay Yong, and Ang Tian-Se. *Fleeting Footsteps. Tracing the Conception of Arithmetic and Algebra in Ancient China*. Singapore: World Scientific, 1992.

A translation and study of the *Sun Zi suan jing* [†SZSJ: The

Mathematical Classic of Sun Zi†], which is meant to reconstruct the Chinese methods of carrying out basic arithmetic operations with counting rods and the early development of algebra in China. It is the authors' contention that "the Hindu-Arabic number system has its origin in the Chinese rod numeral system." But as Jean-Claude Martzloff points out in a review of this work [*Historia Mathematica* 22 (1995), 67-87], "On the whole, these reconstructions are rather convincing even though the terse instructions of the *SZSJ* would allow, in some cases, slightly different interpretations. . . . The comparisons with Islamic techniques are no less convincing. Still, should we conclude that China influenced Islam? Not necessarily. If the Islamic techniques presented here are incontestably posterior to those of the *SZSJ*, another kind of comparison with much earlier Roman computational techniques with counters (calculi) on the Roman counting-board. . . . which were developed well before the *SZSJ*, would have indicated a possible influence in the opposite direction." Despite questions of interpretation and certain technical details (about the dating of the *SZSJ*, the problem of zero in Chinese and Western mathematics, etc.), Martzloff concludes that "the authors have meticulously shed light on many facets of the Chinese historical context: Chinese metrology (pp. 83-88); the socioeconomic context of individual problems (pp. 127-131); the mathematical presentation of problems-in particular the famous 'Chinese remainder problem' (simultaneous congruences of the first degree); and other such topics."

Alexei Volkov in a review of this work ("Lam Lay Yong, Ang Tian Se: *Fleeting Footsteps*". *Archives Internationales d'Histoire des Sciences* 46 (1996), 155-159) remarks on several inaccuracies of the translators and the lack of references to the pioneering works of È. I. Berezkina and to her Russian translation of the *Sunzi suan jing* published as early as 1963. Lam and Ang's book was also reviewed by Maurice Glicksman *Isis* 85 (1994), 499-500.

4295. Raik, Anna Eremeevna. "O vychislenii nekotorykh ob"emov v drevnekitaĭskom traktate Matematika v devyati knigakh". (†The calculation of some volumes in the ancient Chinese treatise *Mathematics in nine books*†.) *Istoriko-matematicheskie issledovaniya* (*Studies in history of mathematics*) 14 (1961), 467-472.

New suggestions and hypotheses are advanced here for the derivation of formulas for the volume of prismatoids in the Chinese classic text, the *Nine Chapters*. K. Vogel points out various shortcomings in the text, including one error noted as early as 1275 by Yang Hui, in his review, **MR** 32 #1090.

4296. Song Jie. "The Historical Value of the *Nine Chapters on the Mathematical Art* in Society and the Economy". In *Chinese Studies in the History and Philosophy of Science and Technology.* Edited by Fan Dainian, and Robert S. Cohen. Translated by Kathleen Dugan, and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 261-266.

This article argues that the *Nine Chapters* is not an abstract mathematical treatise, but provides important historical materials for the study of Han society. The material on the economy of this period demonstrates that traditional Chinese mathematics was distinctly practical, and that classical works on calculation clearly preserve "social content."

4297. Swetz, Frank J. "The Amazing *Chiu Chang Suan Shu*". *Mathematics Teacher* 65 (1972), 425-430.

4298. Swetz, Frank J. *The Sea Island Mathematical Manual: Surveying and Mathematics in Ancient China*. Pennsylvania: Pennsylvania State University Press, 1992.

A Translation of this ancient Chinese mathematical classic, with notes and commentary.

4299. Kurt Vogel, tr. *Chiu chang suan shu: Neun Bücher arithmetischer Technik, Ein Chinesiches Rechenbuch für den praktischen Gebrauch aus den Frühen Hanzeit*. Braunschweig: Friedrich Vieweg Verlag (Ostwalds Klassiker). 1968.

German translation, with introduction and notes, of the Chinese classic text, the *Nine Chapters*. The translation is of the text only, and does not include the important and illuminating commentaries by Liu Hui and Li Chunfeng, among the most important to survive.

4300. Volkov, Alekseĭ [=Alexeï] Karlovich. "O nazvanii odnogo drevnekitaĭskogo matematicheskogo traktata". (†On the title of one ancient mathematical treatise†.) In S. V. Volkov, ed., *Istoriya i kul'tura Vostochnoĭ i Yugo-Vostochnoĭ Azii* (†History and Culture of East and South East Asia†.) Vol. 1. Moscow: Nauka, 1986, 193-199.

The author argues that the conventionally adopted translation for the title of the ancient Chinese classic *Jiu zhang suan shu* as "Mathematics in nine books/ chapters/ sections" is misleading. The word *zhang* did not have the modern meaning of "chapter" at the beginning of the first millennium A.D.; according to the Preface to the treatise by Liu Hui (fl. ca. 263), the *Jiu zhang* originated from the *Jiu shu* ("Nine [types] of computation," the legendary educational curriculum at the end of the second/beginning of the first millennium B.C.; Liu Hui most probably understood *Jiu shu* as the title of the original version of the classic). This allows the author to suggest that the words *jiu zhang* were rather understood by contemporary mathematicians as "nine [classical] topics [of mathematics]," or, roughly, as "[classical] mathematics" per se. He also provides evidence that before the Tang dynasty there existed versions of the text subdivided into 2, 10, and 29 chapters, which support his hypothesis that the words *jiu zhang* do not refer to the number of textual units (chapters) but rather to the number of topics discussed in the treatise. Since the words *suan shu* literally mean "algorithms/procedures (*shu*) [to be performed with] the counting rods (*suan*)," he concludes that the more plausible rendering of the title of the treatise would be "Computational Procedures for the Nine [ancient] Categories [of mathematical methods]" rather than "Mathematics in Nine Chapters/Books."

Volkov goes on to discuss the list of topics associated with the *Jiu shu* as early as in the 1st century A.D.; this list consisted of 13 terms, some of them coinciding with the titles of chapters and names of particular methods in the extant versions of the treatise. An analysis of the numerical parameters of the text (246 problems representing 13 topics) leads him to the hypothesis that the treatise was edited by Liu Xin (46 B.C.-A.D. 23), since these numbers may have been related to the value 41/13 supposedly used by the latter mathematician as an approximation of π.

4301. Volkov, Alekseĭ [=Alexeï] Karlovich. "O strukture traktata Khaĭ dao suan' tszin". (†On the structure of the treatise *Hai dao suan jing*†.) In *17-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov.* (†17th Scientific Conference "Society and State in China." Abstracts of papers†.) Vol. 1. Moscow: Nauka, 1986. 96-99.

This paper is devoted to a formal analysis of the *Hai dao suan jing* (†The computational canon [beginning with the problem about] the island in the sea†) by Liu Hui (fl. ca. 263). The author argues that in ancient China there was a specific practice of composing "non-linear" texts. The reading and understanding of such texts involves their subdivision into smaller "structural units," and the arrangement of these units into cells of a (rectangular) matrix. The author introduces a formal tool for describing the general case of a text which can be associated with the cells of a matrix of n dimensions. The correspondence between the cells and the structural units may have been established with the help of special words or symbols present in the text; the author considers the classical †Book of Changes† (*Yi jing*) as an example of a text which can be associated with the cells of a 2-dimensional matrix with 8×8 cells or a 6-dimensional matrix with $2 \times \ldots \times 2 = 64$ cells. In some cases one cell can be associated with more than one "structural unit." The example of such a text is provided with the *Hai dao suan jing*. The text contains 9 problems naturally identified as the structural units. Each problem deals with the surveying of remote objects using specific instruments (gnomons and T-squares). The author suggests that each structural unit contains three parameters which make it possible to establish a correspondence to the cells of a $2 \times 2 \times 2$ three-dimensional matrix via a correspondence between the units and the so-called trigrams of the †Book of Changes†. This correspondence, in turn, entails a disposition of the problems of the treatise in a two-dimensional 3×3 matrix which can be interpreted as a schematized "map" of an ideal landscape in which the surveyed objects are situated. In conclusion the author briefly mentions the possibility of interpreting the method of analogical inference in terms of multi-dimensional "non-linear" texts.

4302. Volkov, Alekseĭ [=Alexeï] Karlovich. "Structure d'un traité mathématique: l'exemple du *Hai dao suan jing*". In *Modèles et structures des textes chinois anciens*. Edited by K. Chemla, A. Volkov, and V. Lichtmann, (*Extrême-Orient, Extrême-Occident*, 13.) Saint-Denis: Presses Universitaires de Vincennes, Université de Paris VIII, (1991), 93-99.

An abridged French version of item 4301.

4303. Wagner, D. B. "Doubts Concerning the Attribution of Liu Hui's Commentary on the *Chiu-chang suan-shu*". *Acta Orientalia* 39 (1978), 199-212.

This article raises doubts concerning the authenticity of commentaries on the bronze vessel of Wang Mang, and on the sphere, found in the *Jiuzhang suanshu*. Offering several different arguments, this article holds that the commentaries on the vessel should not be attributed to Liu Hui, and that the commentary on the sphere was actually written by Zu Chongzhi.

4304. Wang Ling. *The "Chiu Chang Suan Shu" and the History of Chinese Mathematics During the Han Dynasty.* Dissertation for the Degree of Doctor of Philosophy, 2 volumes. Trinity College, Cambridge, 1956.

4305. Yao Fan. (Yao Fang). "*Chzhou bi suan'tszin* s kommentariem Chzhao Tszyun'tsina". (†The it Zhou bi suan jing with the commentary of Zhao Junqing†.) *Voprosy Istorii Estestvoznaniya i Tekhniki* (*Problems of the History of Natural Science and Technology*) 2(1995), 129-131.

The author provides a discussion on the history of the *Zhou bi suan jing* and the commentaries of Zhao Junqing (alias Zhao Shuang, fl. ca. the 3rd century A.D.). She briefly discusses the geometrical demonstration of the identity $(b-a)(b-a)+2ab=c^2$ for a right-angle triangle with sides (a, b, c) found in the commentary of Zhao Junqing, which is equivalent to the Pythagorean theorem. She concludes that "the mathematical thought of Zhao Junqing was always geometrical: even for algebraic statements he used geometrical proofs .... The geometrical algebra appeared in China and India much earlier than in Greece," (p. 131).

4306. Yao Fan [=Yao Fang]. *Matematicheskie fragmenty iz traktata "Chzhou bi suan' tszin" i kommentariya k nemu Chzhao Tszyun'tsina.* (†Mathematical excerpts from the treatise "*Zhou bi suan jing*" and from the commentaries on the treatise by Zhao Junqing.†) A dissertation presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy ("Kandidat Nauk") in Physics and Mathematics. Scientific advisors: I. G. Bashmakova and

È. I. Berezkina. Moscow: Moscow State (Lomonosov) University, 1995, 144 pp. Unpublished dissertation, defended on June 8, 1995.

The dissertation contains an annotated (partial) translation of the *Zhou bi suan jing* (ca. the early first century A.D.?) and of the commentaries of Zhao Junqing (ca. the 3rd century A.D.) (but not of the commentaries authored by Zhen Luan, ca. 570, and Li Chunfeng, 602-670). The translated part corresponds to pp. 13-43 in the critical edition by Qian Baocong, ed., *Suan jing shi shu* (†Ten mathematical canons†), Beijing: Zhonghua shuju, 1963. The table of contents of the thesis reads as follows: Introduction (p. 3), Chapter 1. Pythagorean triplets and Pythagorean theorem (p. 19), 1.1. Pythagorean triplets (p. 20), 1.2. Pythagorean theorem (p. 27), 1.3. Close relationship between mathematics and philosophy [found] in the treatise *Zhou bi suan jing* (p. 34).

Chapter 2. The Commentary on the *Zhou bi suan jing* by Zhao Junqing (p. 37), 2.1. Mathematical terminology of Zhao Junqing (p. 38), 2.2. Quadratic equations (p. 43), 2.3. Geometrical transformations (p. 54).

Chapter 3. The tradition concerning the similar figures and numerical series (p. 59), 3.1. The *chongcha* method (p. 61), 3.2. Similarity (p. 71), 3.3. Numerical series (p. 76), Conclusions (p. 83), Appendix [an annotated (partial) translation of the first chapter of the *Zhou bi suan jing* with the commentaries of Zhao Junqing] (p. 86), Bibliography [89 entries] (p. 136).

4307. Yao Fan [=Yao Fang]. *Matematicheskie fragmenty iz traktata "Chzhou bi suan' tszin" i kommentariya k nemu Chzhao Tszyun'tsina.* (†The mathematical excerpts from the treatise "*Zhou bi suan jing*" and from the commentaries on the treatise by Zhao Junqing.†) Abstract of the PhD dissertation, Moscow: Russian Academy of Sciences, 1995, 16 pp.

See item 4306.

On Numbers and Numeral Systems

4308. Berezkina, Èl'vira Ivanovna "O matematicheskikh metodakh drevnikh". (†On the mathematical methods of the ancients: on the history of number systems†.) In *Istoriya i metodologiya estestvennykh nauk, 19.* (†History and methodology of the natural sciences, 19†.) Moscow: Moscow State University Press, 1982, 31-40.

This article covers the origins of the number concept as reflected in various tallies and numeral words in early languages, to those used by the Sumerians and ancient Egyptians to the Aztecs. In ancient China, the numerals were purely decimal, with each digit followed by a character for a power of 10. The problem and significance of zero is discussed. Garry J. Tee points out an error with respect to the author's presentation of the numeral system of the Maori of New Zealand, which was not base 11, but base 10, in **MR** 84k:01010.

4309. Chemla, Karine. "Nombres, opérations et équations en divers fonctionnements: Quelques méthodes de comparaison entre des procédures élaborées dans trois mondes différents". In *Nombres, astres, plantes et viscères: Sept essais sur l'histoire des sciences et des techniques en Asie orientale*. Edited by Isabelle Ang, and Pierre-Étienne Will. Paris: Institut des Hautes Études Chinoises, 1994, 1-36.

This article is based on a paper read at the Third International Conference on the History of Chinese Science (Beijing, August 1984). It seeks to compare similar mathematical achievements that were obtained either successively in the same tradition or in different traditions (e.g. Babylonian, Indian, Chinese, Arabic). When considered in terms of methods, achievements that may at first sight seem to be similar are shown to be in fact different, as soon as they are embedded in a broader context, or considered in terms of the mathematical objects and the procedures that manipulate them. On the other hand, historical and conceptual relationships between similar texts can be made more precise by means of such considerations. The paper concludes by emphasizing that the mere translation into modern mathematical terms is insufficient to establish the nature of and possible connections between ancient mathematical texts and methods.

4310. Chemla, Karine. "Nombre et opération, chaîne et trame du réel mathématique. Remarques sur le commentaire de Liu Hui aux *Neuf chapitres sur les procédures mathématiques*". In *Sous les nombres, le monde: Matériaux pour l'histoire culturelle du nombre en Chine ancienne*. Edited by Alekseĭ [=Alexeï] Volkov. (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 43-70.

This paper considers the fact that most of the words that designate numbers in *The Nine Chapters* (and in the commentary on it by Liu Hui, 3rd century) can also designate procedures. It is argued that both numbers and procedures may be considered as realities subject to transformations, and as such are comparable, since the same transformations may be performed on both. An excerpt from Liu Hui's commentary dealing with fundamental operations is discussed with respect both to numbers and to procedures. In each context a different meaning results, in the same way that the computations of an algorithm produce different results depending on the mathematical situations to which they are applied. Chemla discusses, on this basis, the meaning of the term *shu* in *The Nine Chapters* and in Liu Hui's commentary.

4311. Lam Lay Yong. "The Conceptual Origin of our Numeral System and the Symbolic Form of Algebra". *Archive for History of Exact Sciences* 36 (1986), 183-195.

Argues that the Chinese rod numeral system and the Hindu-Arabic numeral system are conceptually identical, and that the Chinese method of handling simultaneous linear equations and polynomial equations on the counting board represent the beginnings of the notational form in algebra. This thesis is developed at much greater length in *Fleeting Footsteps* (item 4294).

4312. Lam Lay Yong. "A Chinese Genesis: Rewriting the History of Our Numeral System". *Archive for History of Exact Sciences* 38 (1988), 101-108.

Summarizes the main points already made in Lam, item 4311, pp. 183-195, and Lam, item 4293, pp. 365-392, and makes the further claim that the Hindu-Arabic numeral system had its origins in the Chinese rod numeral system, based upon some fresh evidence.

4313. Mei Rongzhao. "The Decimal Place-Value Numeration and the Rod and Bead Arithmetics". In *Ancient China's Technology and Science*. Beijing: Foreign Language Press, 1983, 57-65.

This article describes the basic decimal place-value numeration system of ancient Chinese mathematics, along with the role counting rods and the counting board played in calculating. Both the strengths and weaknesses of the latter are considered, along with the later introduction of the abacus. The article includes a photograph of counting rods found in Western Han Dynasty tombs excavated in Qianyang County, Shaanxi Province in 1971. Similar, more extensive and recent archaeological discoveries are also discussed.

4314. Volkov, Alekseĭ [=Alexeï] Karlovich. "Nombres et nombres". In *Sous les nombres, le monde: Matériaux pour l'histoire culturelle du nombre en Chine ancienne*. Edited by A. Volkov (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 5-11.

This paper introduces a collection of articles edited by the author, the point of which is to describe uses of numbers in various domains of Chinese thought and life. Marcel Granet had already shown the import of numbers in key domains in China. The collection of papers published here aims at raising questions which Granet did not discuss, such as the origin of number as a linguistic unit in archaic Chinese; the understanding of number by ancient Chinese mathematicians; the various names and representations of numbers, and how number was involved in theological discussions; the uses of number as a tool to organize the world. The introduction gives the main arguments of the articles gathered in the volume, and brings to light several common features that lead to some general conclusions.

4315. Volkov, Alekseĭ [=Alexeï] Karlovich. "Large Numbers and Counting Rods". In *Sous les nombres, le monde: Matériaux pour l'histoire culturelle du nombre en Chine ancienne.* Edited by A. Volkov (*Extrême-Orient, Extrême-Occident*, 16.) Saint-Denis: Presses Universitaires de Vincennes, 1994, 71-92.

This paper treats the problem of the finiteness of numbers formulated in the 3rd century treatise *Shu shu ji yi* by Xu Yue, along with the 6th-century commentary by Zhen Luan. The author suggests that the treatise may have been related to debates on the Buddhist notion of reincarnation which took place in China in the first half of the first millennium A.D. An obscure reference to a theoretical construction which allowed one to obtain numbers as large as desired (similar to that of Archimedes's *Sand-Reckoner*) is discussed, as well as the role of counting devices in establishing a general notion of number.

4316. Yang Lien-sheng. "Numbers and Units in Chinese Economic History". In *Studies in Chinese Institutional History.* (Harvard-Yenching Institute Studies, No. 20.) Edited by Yang Lien-sheng. Cambridge: Harvard University Press, 1961, 75-84.

Yang, primarily a scholar of Chinese economic history, notes here "certain precautions which should be observed in the use of numbers and units in Chinese texts." From misprints and copyists' errors, he goes on to discuss pseudo numbers like *ch'ien chin*, which often means "large amount" and not necessarily 1,000 pieces of gold. Similarly, 3 and 9 may simply mean "several" and "many," and may not be intended literally (p. 77). The author further considers the problem of different local units and measures in different places, with similar variations applying to times. The article concludes with discussion of standard weights and measures, and the problem in classical texts of converting various units from one system to another.

4317. Zinin, Sergeĭ Vasil'evich. "O genezise kitaĭskoi numeratsii". (†On the genesis of Chinese numerals†.) In *Drevniĭ i srednevekovyĭ Vostok.* (†Ancient and Medieval East†.) Vol. 1. Moscow: Nauka, 1985, 93-99.

The author discusses the ancient forms of Chinese numerals and voices his doubts concernig the thesis of Joseph Needham and Wang Ling concerning the early use of a place-value principle in ancient China.

Fractions and Decimal Fractions

4318. Berezkina, Èl'vira Ivanovna "Iz istorii desyatichnykh drobeĭ v Kitae". (†From the history of decimal fractions in China†.) *Matematika v shkole* (*Mathematics in school*) 17 (1963), 261-271.

4319. Berezkina, Èl'vira Ivanovna "On the Early History Of Decimal Fractions". *Actes du XI Congrès Internationale d'Histoire des Sciences*. (Varsovie-Cracovie, 1965), Sect. III: Histoire des Sciences Exactes (Astronomie, Mathématiques, Physique). Wroclaw: Ossolineum, 1968, 157-159.

Oracle bones from the 14th century B.C. are described, upon which numbers reflecting decimal notation without place value are identified. Most of the article is devoted to discussion of the *Sunzi suan jing*, wherein Sunzi gives a list of measures of length, mostly decimal; two methods of division and root extraction involving decimal fractions are also discussed. Reviewed by E. B. Allen in **MR** 42 #2909.

4320. Chemla, Karine. "Les fractions comme modèle formel en Chine ancienne". In *Histoire de fractions, fractions d'histoire*. Edited by P. Benoit, K. Chemla and J. Ritter. Basel: Birkhäuser, 1992, 188-207.

This paper analyzes the arithmetic of fractions contained in the *Nine Chapters*, and proofs of the algorithms offered by Liu Hui. Two main conclusions are drawn. First, the description of the algorithm for the addition of fractions does not make clear the reasons why the algorithm is correct. However, Liu Hui rewrites it in such a way that the new description of the algorithm shows the reasons why the algorithm is correct. Moreover, in establishing the reasons for the correctness of the algorithm, Liu Hui's proof at the same time analyzes how the algorithm proceeds. On the basis of such a proof, he reveals formal connections between this algorithm and others. Second, the algorithm for the division of fractions is of the same nature as the algorithms which Liu Hui rewrote for his proofs of the algorithms for the addition of fractions.

4321. Mikami, Yoshio. "Arithmetic with Fractions in Old China". *Archiv for Mathematik og Naturvidenskab, B* 32 (3) (1911), 3-10.

This article demonstrates that ancient Chinese mathematicians freely used fractions in arithmetic operations and compared different applications of fractions with evidence from the *Zhou Bi Suan Jing*, the *Jiu Zhang Suan Shu*, *Sun Zi Suan Jing*, as well as the *Zhang Qiu-Jian Suan Jing*.

4322. Wang Ling. "The Development of Decimal Fractions in China". *Proceedings of the 8th International Congress on the History of Science*. Florence, 1956, 13-17.

Measures and Standard Measuring Vessels

4323. Bai Shangshu. "An Exploration of Liu Xin's value of π from Wang Mang's Measuring Vessel". *Sûgaku shi kenkyû* 116 (1988), 24-31.

4324. Poor, Robert. “The Circle and the Square: Measure and Ritual in Ancient China”. *Monumenta Serica* 43 (1995), 159-210.

This paper deals with the origins of measure in ancient China, moving from the early bronze age back into the “mute terrain” of prehistory. Based upon surviving pottery, bronze, and jade objects, the author believes that an “unseen mathematical structure must have been deliberately planned in the design of the objects he considers” (p. 168). Poor concludes that “the calculations that governed the structure also provided a mental content, an imprint of the mind of the maker, so to speak,” (p. 178). This process is interpreted as an “empowering device,” since it “fosters standards, rules, and the formation of an orthodox canon which we recognize as official,” (p. 179).

4325. Reifler, Erwin. “The Philological and Mathematical Problems of Wang Mang’s Standard Grain Measures”. In *Qingzhu Li Ji xiansheng qishi sui lunwen ji.* (†Collected Papers in Honor of Dr. Li Ji’s Seventieth Birthday.†) Taipei, 1965, 387-402.

This article provides a good description of the bronze vessel of Wang Mang with the text and translation of five of its six inscriptions. It also provides a number of primary and secondary sources. The conclusions of the article, however, should be considered with due caution.

4326. Volkov, Alekseĭ [=Alexeï] Karlovich. “Predvaritel’nye rezul’taty kolichestvennogo analiza drevnekitaĭskikh etalonnykh sosudov”. (†Preliminary results of the quantitative analysis of ancient Chinese standard vessels†.) In *16-aya Nauchnaya Konferentsiya “Obshchestvo i Gosudarstvo v Kitae.” Tezisy dokladov.* (†16th Scientific Conference “Society and State in China.“ Abstracts of papers†.) Vol. 1. Moscow: Nauka, 1985, 145-150.

The author presents his findings on the values of π used by ancient Chinese mathematicians who calculated the dimensions of standard measuring vessels. The vessels were of cylindric shape and their dimensions (diameter, height, and volume) were inscribed on their surfaces and/or recorded in historical documents. The author considers the description of the vessel *Fu* designed in the second half of the first millennium B.C., as well as the computations of the dimensions of the vessels of the 1st-5th centuries A.D. performed by Liu Xin (46 B.C. -A.D. 23), Liu Hui (fl. ca. 263), Zu Chongzhi (429-500), and Li Chunfeng (602-670). The author shows that in the construction of the vessel *Fu* the value 25/8 (the “Babylonian value”) was used. As for the other vessels, the author’s findings are based on two assumptions: (1) the values of the dimensions were truncated after a certain number of decimal figures, and (2) the value of π that was used was always expressed as a common fraction. The author mentions a simple method for evaluating the interval including the possible values of π and for determining several common fractions which may have been used (in particular, he restores Liu Xin’s value as 41/13). Although the relevant formulas are not provided, they may be found in the author's doctoral dissertation (1988). A revised and extended version of this paper was published in English in two parts. See items 4327 and 4328.

4327. Volkov, Alekseĭ [=Alexeï] Karlovich. "Supplementary Data on the Values of π in the History of Chinese Mathematics". *Philosophy and the History of Science. A Taiwanese Journal* 3 (1994), 95-110.

The paper presents the results of a quantitative analysis of several ancient and early medieval Chinese standard measuring vessels. The method used by the author is based on the same assumptions as those discussed in his 1995 paper, item 4328. He focuses on the following topics: (1) the re-calculation of Liu Xin's (46 B.C.-A.D. 23) measuring vessel *Hu* by Zu Chongzhi (429-500); (2) the re-calculation of the ancient vessel *Fu* by Zu Chongzhi; (3) the value of π used by the makers of the vessel *Hu* of the Wei dynasty (220-264), and Liu Hui's (fl. ca 263) calculation of the dimensions of the same vessel; (4) the jade vessel *Dou* of the Jin dynasty (265-420) and its re-calculation by Li Chunfeng (602-670); (5) the value of π used by He Chengtian (370-447). The author discusses the approximate values of π which can have been used by Zu Chongzhi and Liu Hui, and also suggests several approximations of π probably used by Chinese mathematicians and hitherto unknown to historians of mathematics.

4328. Volkov, Alekseĭ [=Alexeï] Karlovich. "Quantitative Analysis of Liu Xin's Standard Measuring Vessels." In *Tradition and Beyond. Papers from the 7th International Conference on the History of Science in East Asia, Kyoto, 2-7 August, 1993.* Edited by Keizô Hashimoto, Catherine Jami, and Lowell Skar. Osaka: Kansai University Press, 1995, 377-384.

This paper presents the results of the quantitative analysis of ancient Chinese standard measuring vessels devised in the early 1st century A.D. under direction of the famous literatus, mathematician, and astronomer Liu Xin (46 B.C.-A.D. 23). Each of the vessels considered here had the shape of a cylinder, and the artisans who crafted them, as well as later commentators, strove to calculate with a high degree of precision the value of the diameter corresponding to a given (standard) volume and the approximate value of π they had. These parameters allow contemporary historians to solve the inverse problem and to calculate the approximate value of π adopted by the ancient authors. Here Volkov makes two assumptions: (1) the descriptions of the vessels found in historical records contained truncated decimal fractions; (2) Chinese mathematicians used common (not decimal) fractions p/q to express approximations for the value of π. This means that a decimal fraction xx.yyy in the description of the vessel should be interpreted as designating some value belonging to the interval [xx.yyy000…, xx.yyy9999…]. The inverse calculation in this case produces an interval in which one should look for the original common fraction used as an approximate value of π by ancient mathematicians. The author provides the relevant formulae, analyzes 8 vessels made by Liu Xin and finds that there are only two common fractions $p/q, q < 100$, belonging to all of the intervals obtained: $41/13 = 3.1538461\ldots$, and $306/97 = 3.1546391\ldots$. Volkov concludes that Liu Xin most probably used the value $41/13$ for π.

Magic Squares

4329. Cammann, Schuyler. "The Evolution of Magic Squares in China". *Journal of the American Oriental Society* 80 (1960), 116-124.

This article, to some extent, is a review and commentary on Joseph Needham's account of magic squares in item 4225, volume 3 of *Science and Civilization in China*, pp. 55-62. The article says that "[Needham] quite misrepresented the actual story; thus, it seems worthwhile to cover the ground again, to try to put things back into their proper perspective," (p. 116).

In telling his "true" story, the author doubts first of all that the Chinese had invented the magic square of three in the 23rd century B.C., while agreeing with Needham upon Chinese priority of magic squares of this order in general. Secondly, the author argues that some magic squares, of orders four and eight as recorded in Yang Hui's work, "were most probably foreign borrowings" from the Arabs (p. 120). Schuyler points out, wrongly (as later corrected by Lam Lay-Yong in item 4449, *A Critical Study of the Yang Hui Suan Fa*), that Yang Hui did not give his method of the construction of magic squares of order four as Needham claimed. Thirdly, the author asserts that Cheng Dawei (1533–1606) was not an important inventor of magic squares, but an ineffective transmitter, and that the works of other mathematicians in the Qing dynasty, such as Fang Zhongtong (fl. ca. early 18th century), Zhang Cao, and Bao Qishou "have nothing to do with magic squares and are far more primitive" in comparison with the development of the subject in Europe (p. 123). In conclusion, the author writes that the "Chinese were too often satisfied by preliminary results based on an early-discovered method, without trying to improve upon this" (p. 124).

4330. Cammann, Schuyler. "The Magic Square of Three in Old Chinese Philosophy and Religion". *History of Religions* 1 (1961), 37-80.

Beginning with the Chinese records of the *Luo Shu*, the magic square of three, which has been dated as far back as the fourth century B.C., the author goes on to discuss the philosophical meaning of the *Luo Shu* between the fourth century B.C. and the second century A.D. The article points out that the *Luo Shu* represents the concept of centrality, a longed-for ideal in this period. In the third and fourth sections, the article investigates the relation between the *Luo Shu* and both the

Yin-Yang and Five-Elements theories, and how the *Luo Shu* reflects or represents these theories.

4331. Cammann, Schuyler. "Old Chinese Magic Squares". *Sinologica* 7 (1962), 14-53.

Jock Hoe *Annals of Science* 39, (1982), p. 503, points out that Lam Lay Yong's study of the *Yang Hui suanfa* (1977) refutes Cammann's contention that Yang Hui never described how to construct magic squares of order 4. He also notes that it is "odd" that Cammann criticizes Yang Hui's method for constructing magic squares as "rather clumsy."

4332. Ho Peng-Yoke. "The Earliest Chinese Magic Squares and Magic Squares in the Islamic Word". *Bantai xuebao* 5 (1972), 95-104.

4333. Rou, Arion. "Les carrés magiques et l'histoire des idées en Asie". *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 139 (1989), 120-158.

The author relates magic squares to Indian therapeutic medical practice, "d'un emploi pensiblement plus rare," (p. 120). Reference is made to Dürer's use of the magic square of order 4 in his engraving, *Melancholia* (1514) (see *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 103 (1953), 308-314); comparisons are drawn with neo-Pythagorean ideas, Arabic magic squares, and the Chinese *Luo Shu* (pp. 134-135). Rou discusses developments of magic squares in China, above all in the Tang and Song dynasties, and concludes that what began as a mythic diagram, *Luo Shu*, and as a talismanic practice, became the subject of scientific investigation in Europe in the 17th century, for example in the works of Pascal.

4334. Swetz, Frank J. "Mysticism and Magic in the Number Squares of Old China". *Mathematics Teacher* 71 (1978), 50-56.

Mathematics and the Yi Jing

4335. Chemla, Karine. "Croisements entre réflexion sur le changement et pratique des mathématiques en Chine ancienne". In *En suivant la voie royale. Mélanges en l'honneur de L. Vandermeersch.* Edited by J. Gernet and M. Kalinowski. Paris: Presses de l'École Française d'Extrême-Orient, 1997, 191-205.

If mathematicians in ancient China mainly worked on the basis of procedures, this may have been due, so the author argues, at least in part to the fact that procedures were conceived of as embodying change (*bianhua*) in mathematics. As in other domains, such motivations of a philosophical nature seem to have been inspired by the *Yijing*, and more specifically its "great commentary." After discussing the use Liu Hui (in his commentary on *The Nine Chapters*) made of such terms as *bianhua* and *hua* to designate the procedures or their workings, the author shows that Liu Hui's use of *hua* coincides with the later Mohist definition for it, as well as with some uses of the term by Huangdineijing and Xunzi. The article concludes by showing how, in Liu Hui's proofs of the procedures used in the classic text, he exhibits fundamental patterns of change, the generality of which goes beyond the borders of mathematics. In fact, it is shown that the *Hanshu* identifies such a fundamental pattern of change in the same way as do various economic measures, the design of which in some cases is historically linked to *The Nine Chapters*, and that the *Hanshu* explicitly associates such patterns of change with the *Yijing*.

4336. Chemla, Karine. "Philosophical Reflections in Chinese Ancient Mathematical Texts: Liu Hui's reference to the *Yijing*". In *Proceedings of the VIIIth International Conference on the History of Science in East Asia*. Edited by Kim Yungsik. in press.

This paper argues that mathematicians in Ancient China worked primarily on the basis of algorithms not only because these were appropriate to practical ends, but also because they were conceived of as embodying change (*bianhua*) in mathematics. As in other domains, such motivations of a philosophical nature seem to have drawn on the *Yijing*, and more specifically on its "Great commentary." Chemla provides evidence taken from Liu Hui, the Wei-Jin commentator on the Han classic, *The nine chapters on the art of mathematics*. The last part of the paper shows how, in his proofs of procedures used in the *Nine chapters*, Liu Hui exhibits fundamental patterns of change which, in their generality, go beyond the borders of mathematics.

4337. Dong Guangbi. "The Book of Changes and Mathematics". In *Chinese Studies in the History and Philosophy of Science and Technology*. Edited by Fan Dainian and Robert S. Cohen. Translataed by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 125-136.

Describing the *Yi Jing* as a "classic system of symbols and concepts," Dong Guangbi considers both the philosophical theories and mathematical logic of its "symbol system." He discusses the connection Leibniz drew between the Graph of Changes (*Yi Tu*) and binary numbers. In the 20th century, the author describes the explanations of the eight trigrams and 64 hexagrams of the *Yi Jing* by Shen Zhongtao, Xue Xueqian, Ding Chaowu, and others in terms of binomial expansions and algebraic matrices. Finally, Dong describes Shao Yong's interpretation in terms of geometry and group theory.

Interpolation Methods and the Chinese Calendar

4338. Ang Tian-Se. "The Use of Interpolation Techniques in Chinese Calendar". *Oriens Extremus* 23 (1976), 135-151.

Discusses the interpolation methods used in compiling several Chinese Calendars, focusing on the Huang Ji Li calendar by Liu Zhou (544-610), the Ling De Li calendar by Li Chunfeng in the second part of the seventh century, and the Shou Shi Li calendar by Guo Shoujing and Wang Xun in 1281.

Counting Rods and Counting Board Calculation

4339. Ang Tian-Se. "Chinese Computation with the Counting-Rods". *Kertas-Kertas Pengajian Tionghua* (*Papers on Chinese Studies*) 1 (1977), 97-109.

4340. Lam Lay Yong. "Linkages: Exploring the Similarities Between the Chinese Rod Numeral System and our Numeral System". *Archive for History of Exact Sciences* 37 (1979), 365-392.

Concerns the Chinese methods of calculating with rod numerals and writing the results, with instructions for how to use counting rods to carry out the four basic arithmetic operations. In addition to these, the article also shows how Chinese handled fractions, as well as the extractions of square roots and cube roots on counting boards. By considering all of these techniques, the paper concludes that Chinese procedures closely resemble the ones used today.

4341. Chemla, Karine. "Positions et changements en mathématiques à partir de textes chinois des dynasties Han á Song-Yuan. Quelques remarques". In *Disposer pour dire, place pour penser, siteur pour agir.* Edited by Karine Chemla. (*Extrême-Orient, Extrême-Occident*, 18.) Saint-Denis: Presses Universitaires de Vincennes, 1996, 114-147.

In order to account for the frequent occurrence of place-value notations in Chinese mathematical texts, it is helpful to embed them within a broader context: the use which Chinese mathematicians made of positions when computing on a surface with counting-rods. A reconstruction of this practice shows that positions are dynamic entities and in fact are the actual objects on which computations bear. As a result, place-value notations appear to involve a specific kind of such dynamic entities: those whose behavior in a computation present a uniformity. This fact relates their recurrence to the aims pursued in the study of algorithms.

4342. Volkov, Alekseĭ [=Alexeï] Karlovich. "Counting Rods". in *Instruments of Science: An Historical Encyclopedia*, Edited by R. Bud and D. J. Warner. London, New York: Garland, 1998, 155-156.

An encyclopedia article concerning the history of counting rods in ancient and medieval China. The author briefly explains the principles of the representation of numbers and polynomials with the instrument.

The Abacus

4343. Goshkevich, I. "O kitaĭskikh schetakh". (†On the Chinese abacus†.) In *Trudy chlenov Russkoĭ Duhovnoĭ Missii v Pekine*. (†Works of the members of the Russian religious mission in Peking†.) Vol. 2. St.

Peterburg, 1853, 169-194. German translation: "Über das chinesische Rechenbrett". Berlin, 1858.

4344. Lau Chung Him. *The Principles and Practice of the Chinese Abacus.* Hong Kong: Lau Chung Him and Co., 1958/1980.

This book is written as an elementary course in the use of the Chinese abacus. Chapter one gives a brief (and in certain points unreliable) account of the development of the physical object itself. Chapters two through four discuss how to use the abacus for addition, subtraction, and multiplication, respectively. The following four chapters are devoted to explaining division. The book is illustrated with 579 figures, and Chinese rhymes used to help memorize computational methods are also included.

4345. Mikami, Yoshio. "The Influence of Abaci on Chinese and Japanese Mathematics". *Jahresbericht der Deutschen Mathematiker Vereinigung* 20 (1911), 380-393.

This work discusses the central and pervasive role that the abacus has played in the development of Chinese and Japanese mathematics, both directly and indirectly. The two forms of the abacus considered here are the ancient counting rod system that carried out calculations on a counting board, and the much later development of the mechanical abacus, a technological devise. The use of positive and negative numbers and methods for solving equations are also explained. A brief account of the abacus in modern Japan concludes the article, with the comment that while it was very convenient in daily-life situations, it was not suitable for root extractions of an equation, which still requires the old method of the counting rods.

4346. Pullman, J. M. *The History of the Abacus.* New York: Praeger, 1968.

This book focuses primarily on the history of the Roman abacus. As for the Chinese abacus, it is mentioned only in passing as follows: "The similarity of the Roman bead-frames to those used in some Eastern countries today suggests that the use of such instruments spread in some way from Rome to China and thence to Japan and Russia. It would be difficult, however, to establish any direct connection, for little is known of the early history of the Chinese suanpan. It was mentioned once or twice in early histories of Chinese mathematics, but rules for its use did not appear until the thirteenth century," (p. 20).

4347. Taisbak, C. M. "Roman Numerals and the Abacus". *Classica et Mediaevalia* 26 (1965), 147-160.

4348. Yamazaki Yoemon. "The Origin of the Chinese Abacus". *Memoirs of the Research Department of the Toyo Bunko* 18 (1959), 91-140.

This work discusses conflicting debates over the origins of the abacus (the Han period theory, Song period theory, the Yuan period theory, the Ming period theory, and the Qing period theory). It lists authors who have supported one or another of these theories and the sources on which they rely; Mikami, for example, favored the Song period theory, which D. E. Smith followed in his *History of Mathematics* (1925). The author favors the Han theory, and bases his conclusion on the account in the *Shu Shu Ji Yi* by Hsu Yo (Xu Yue) , and annotated by Chen Luan (Zhen Luan) of the Northern Zhou period. The author examines the origins of the abacus, especially with respect to methods of calculation, especially division, and based on the methods of calculation, believes the abacus was introduced to China from Rome.

4349. Yamazaki, Yoemon. "History of Instrumental Multiplication and Division in China-from the Reckoning-blocks to the Abacus". *Memoirs of the Research Department of the Toyo Bunko* 21 (1962), 125-148.

This paper examines the various circumstances under which the methods of multiplication and division by means of instruments were developed since remote antiquity. The history begins with legendary accounts that are hardly acceptable. Yamazaki then proceeds to study the development of methods for multiplication and division based on reliable materials from the Three Kingdoms period (ca. 220-280), when the first clear records of calculating using instruments were written, to the end of the Ming Dynasty (1368-1644) when use of the abacus was widely diffused. Ancient methods are described for multiplication and division, simplified calculations introduced in the *Xiahou Yang Suan jing*, and simpler methods introduced in the Tang and Song periods. The author also associates use of calculating rods with taxation officers and mathematicians, whereas the abacus was used by the masses and less intellectual tradesmen. Changes in methods of multiplication and division which the author discusses served to facilitate use of the abacus.

Arithmetic

4350. Biernatzki, K. L. "Die Arithmetik der Chinesen". *Journal für die Reine und Angewandte Mathematik* 52 (1856), 59-94; Reprinted Martin Saendig, 1973 ; French translation by O. Terquem. *Nouvelles Annales de Mathématiques* 1 (1862), 35-44, and 529-540.

As a basic source the author used "Jottings on the Science of Chinese Arithmetic" which appeared in the *Shanghai Almanac for 1853 and Miscellany*; no mention is made that Alexander Wylie was the author of this article upon which Beirnatzki's German version is based. For Wylie's original series of articles, see item 4354.

4351. Lam Lay Yong. "On the Chinese Origin of the Galley Method of Arithmetical Division". *British Journal for the History of Science* 3 (1966), 66-69.

This short essay discusses the origin of the European galley method for division, the batello or scratch method. After outlining the general procedures of the galley, and that of Hindu and Chinese methods of division respectively, the article draws the conclusion that the galley method "originated in China and from there it was transmitted to India and thence to Europe," (p. 69). The article points out that the galley method was ironically reintroduced back into China at the beginning of the 17th century.

4352. Lam Lay Yong. "The Development of Hindu-Arabic and Traditional Chinese Arithmetic". *Chinese Science* 13 (1996), 35-54.

This paper discusses the method Liu Hui (3rd century) used to approximate the value of pi. A translation of Liu's method is given in an appendix. The author also considers the values for pi given by Zu Chongzhi (429-500), which remained unsurpassed for a millennium. Although the method used by Zu is no longer known, it is almost certain that he applied Liu's method. With the aid of an electronic computer, a table of computations adhering to Liu's method is given to indicate the possible derivation of Zu's results. The paper concludes with a survey of the history of circle measurements in China.

4353. Terquem, Olry. "'Arithmétique et Algèbre des Chinois' par M. K. L. Biernatzki Doctuer á Berlin". *Nouvelles Annales de Mathématiques.* Vol. 1 (1862), 35, and Vol. 2 (1862), p. 529.

A French translation of the work by Biernatzki (item 4350), based on the account of Chinese mathematics given by Alexander Wylie (item 4354).

4354. Wylie, Alexander. "Jottings on the Science of Chinese Arithmetic". *North China Herald* (Aug.-Nov. 1852, nos. 108-113, 116, 117, 119-121). Reprinted in *Chinese Researches*, Shanghai, 1897 ; London: K. Paul, Trench, Trubner & Co., 1937 ; Taipei: Ch'eng-wen, 1966, 159-194.

This article is the first in English to give a reliable account, for the most part, of Chinese mathematics. It begins with a description of the legendary origins of Chinese mathematics, followed by a general survey of some important extant texts, including the *Ten Classics*, Qin Jiushao's *Shu Shu Jiu Zhang*, the *Yang Hui Suan Fa*, and Li Ye's *Ce Yuan Hai Jing*, among others. Special attention is given to the explanation of procedures for indeterminate analysis found in the *Sun Zi Suan Jing* and in Qin's book; and of the *Tian Yuan Shu* (method of the celestial element) in Li Ye's works, and of Qin's method for solving higher numerical equations. For the latter, the author points out that Qin anticipated Horner, who published a similar method in 1819. In the last part of this paper, Wylie discusses the works of mathematicians in the late Qing dynasty, including Li Rui, Luo Shilin, Li Shanlan, and Dai Xu.

Given the pioneering nature of this work, it is not surprising that it contains various errors and inaccuracies. For instance, Wylie's faulty interpretation of the four elements in the *Si Yuan Yu Jian* (pp. 186-187), wrong dates for Liu Hui and Zhao Shuang, and misattribution of the authorship of the *Wu Cao Suan Jing* (p. 165), among others. Nevertheless, the "Jottings" is an important work for the history of Chinese mathematics, and was to have a significant influence upon such prominent historians of mathematics as Moritz Cantor, Florian Cajori, and David E. Smith

Algorithms

4355. Chemla, Karine. "L'aspect algorithmique récurrent dans les mathématiques chinoises: Paysages d'algorithmes, algorithmes de paysages". Edited by Jean Dhombres. *Cahiers d'Histoire et de Philosophie des Sciences* 20 (1987), 86-104.

This paper follows Donald Knuth's suggestion to study ancient Babylonian texts from the point of view of algorithmic theory. This idea was put into play for the study of ancient Chinese mathematical texts by Wu Wenjun. The author follows the same approach and describes a research program which could be implemented for the study of algorithms carrying out arithmetical operations. The root extraction algorithms found in the *Nine Chapters*, in the *Mathematical Treatise by Sunzi*, and in the *Mathematical Treatise by Zhang Qiujian* provide examples on the basis of which this research program is further described.

4356. Chemla, Karine. "Should they read FORTRAN as if it were English?". *Bulletin of Chinese Studies* 1 (1987), 301-316.

This paper was given at the Second International Conference on the History of Chinese Science, Hong Kong, December 1983. It is devoted to an analysis of algorithms per se in the history of mathematics. The root extraction algorithms found in the *Nine Chapters on the Art of Mathematics*, and in the classic texts of Sunzi and Zhang Qiujian, provide examples of different kinds of analysis and how they were performed. The algorithms found in the *Nine Chapters* depend upon division and make use of iteration, conditionals, and assignments of variables. Although these are all familiar algorithmic methods, none of these components are found in Babylonian algorithms. This article then examines differences between the algorithms in the *Nine Chapters*, and those contained in the classic treatises by Sunzi and Zhang Qiujian. These bear mainly on the description of some auxiliary computations. The key point is that the small differences between them are not insignificant variations, but are of great importance for the history of the concept of equation developed in China. The conclusion stresses that algorithms that may seem equivalent from the point of view of modern mathematics are actually quite different in important ways when understood in their historical contexts. Therefore, a careful analysis of the way in which a text describes a particular algorithm should always be performed at the same time as one assesses its mathematical content.

4357. Chemla, Karine. "De l'algorithme comme liste d'opérations". In *L'Art de la liste*. Edited by François Jullien. (*Extrême-Orient, Extrême-Occident*, 12.) Saint-Denis: Presses Universitaires de Vincennes, Université de Paris VIII, 1990, 79-94.

The hypothesis developed in this paper is that the actual form of Chinese mathematical texts is in itself meaningful. More precisely, the lists of prescribed computations that constitute an algorithm convey explicit mathematical meaning. Two examples are given. The sequence of computations given in the *Nine Chapters* in order to perform a root extraction is shown to have a specific mathematical property. Likewise, procedures given to compute the volume of a truncated pyramid are exactly those that are used for the proof of the result. This is established by showing that Liu Hui's proof for this algorithm has the same structure as the algorithm itself. Therefore, it seems that Liu Hui found the elements of his proof based upon the description of the algorithm found in the *Nine Chapters*.

4358. Chemla, Karine. "Theoretical Aspects of the Chinese Algorithmic Tradition (first to third century)". *Historia Scientiarum* 42 (1991), 75-98.

This paper investigates the practice and aims of algorithmic activity in ancient China. First, it is argued that one aim of the *Nine Chapters* and the commentaries written by Liu Hui was to identify general patterns in computational procedures and then to rewrite algorithms that at first seemed to be different in order to unify them. This would mean that there is an algebraic aspect to this practice of algorithms which the paper then compares with other conceptions of algebra in the history of mathematics. Second, the aims of proofs may also have been to identify such fundamental patterns, which the author argues were connected with demonstrating the correctness of the algorithms. This may in turn explain why proofs sometimes led to a rewriting of the algorithms in such a way that the new descriptions of the algorithms also indicated the reasons why they were correct. The paper concludes by showing how both aspects of algorithms described above are connected to one another.

4359. Volkov, Alekseĭ [=Alexeï] Karlovich. "Algoritmicheskiĭ kharacter drevnekitaĭskikh matematicheskikh tekstov". (†Algorithmic character of ancient Chinese mathematical texts†.) In *21-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov.* (†21st Scientific Conference "Society and State in China. 11 Abstracts of papers†.) Moscow: Nauka, 1990, part 1, 51-54.

The author suggests that the language of ancient Chinese mathematical texts written as sequences of arithmetical operations can be considered as a programming language for an abstract computing machine. He argues that the established practice of rendering Chinese algorithms as modern mathematical formulae sometimes conceals important aspects of the texts, and highly regards the suggestions of Jock Hoe, item 4444 and Karine Chemla, item 4437 that the algorithms should be rendered with the help of a "quasi-assembly language." He provides a preliminary analysis of the structure of "elementary operations" (consisting of an "Operation Code" and of up to two "Operands") and a classification of these two constituents. He remarks that some of the "Operation Codes" functioned as the names of "subprograms" and that the "realization" of the subprograms may have varied from one "school" of mathematicians to another. This may have made certain algorithms "transferable," that is, they could have been used notwithstanding the use of counting devices and the realization of elementary operations.

Irrational Numbers

4360. Chemla, Karine. "Des nombres irrationnels en Chine entre le premier et le troisième siècle". *Revue d'Histoire des Sciences* 45 (1992), 135-140.

This paper argues that the technical expression found in the *Nine Chapters on the Art of Mathematics*, "yi mian ming zhi," should be understood as "with root, name it," which introduced irrationals as results of square root extractions. A comparison is then made with the introduction of fractions. Reviewed by Jami, Catherine in **MR** 93m:01013.

4361. Chemla, Karine. "Fractions and Irrationals Between Algorithm And Proof In Ancient China". *Studies in History of Medicine and Science* (New Series) 15 (1-2) (1997-98), 31-54.

This article argues that the introduction of fractions and irrationals in the *Nine Chapters* may be related to the use of a form of algebraic proof in ancient China. Chemla analyzes the reasons why quadratic irrationals were introduced at about the beginning of the common era. She then argues that the *Nine Chapters* and the commentary on it which Liu Hui is said to have completed in 263 A.D. attest to a practice of algebraic proof within an algorithmic context. Chemla also sketches how this relates to philosophical inquiries on change developed in China. In closing, she emphasizes that far from being independent of each other, introduction of irrationals, specific practice of proof encountered in ancient Chinese sources such as Liu Hui's commentary, and philosophical reflections on change which developed from within mathematics, are three closely connected phenomena.

Root Extractions and Horner's Method

4362. Chemla, Karine. "Similarities between Chinese and Arabic Mathematical Documents (I): Root Extraction". *Arabic Sciences and Philosophy* 2 (4) (1994), 207-266.

Chinese, Indian, and Arabic documents, respectively from the 1st, 5th, and 9th centuries onward, contain similar tabular procedures for extracting square and cube roots in place-value numeration systems. Moreover, Jia Xian, an 11th-century Chinese astronomer, as well as al-Samaw'al, a 12th-century Arab mathematician, extracted roots of higher order with the so-called Ruffini-Horner procedure. This article attempts to define a textual method of organizing this corpus by distinguishing relevant criteria with which to identify similarities and differences from historical as well as conceptual points of view. A first part analyzes three different stages in the descriptions of algorithms in China between the 1st and the 11th centuries. The rewriting of algorithms that progressively advances from one stage to the next shows a uniformity in components of the algorithms which culminates in procedures of the Ruffini-Horner type. Textual criteria demonstrate a greater affinity between algorithms such as those described by Kushyar ibn Labban (c. 1000) and Chinese texts than with Indian ones, which are in turn closer to algorithms described by al-Khwārizmī. Criteria of the same kind link algorithms of Jia Xian and al-Samaw'al, as well as those of Kushyar and al-Samaw'al.

4363. Gauchet, L. "Note sur la généralisation de l'extraction de la racine carré chez les anciens auteurs chinois et quelques problèmes du *Jiuzhang suanshu*". *T'oung Pao* 15 (1914), 531-550.

General methods of root extraction reached their full development in China in the 13th century using the (*Tianyuan*) algebra, but the terminology was fluid and not fixed. Even so, all references to root extractions included the two characters (*kai fang*). This article considers the generalization of the square root, examines the influence of early Jesuits in China, and examines the general problem: given the surface of a rectangle and the difference between its two sides, to find the two sides. The author contrasts Chinese methods with those in the West (e.g. Horner's method), and compares "mentalities"—namely, the Chinese method of generalized extraction of roots to Horner's method of resolving numerical equations. But despite the analogy of the processes, the author cautions that one should not overlook the differences in ideas from a mathematical point of view. The Chinese generalized the extraction of roots for the solution of numerical problems. This was the inverse of what happened in the West, he maintains, where proceeding algebraically on the basis of equalities (China, the author points out, did not have the = sign or an equivalent notation until after the arrival of the Jesuits), European mathematicians were used to studying the theory of equations and finding solutions in terms of a general formula. The Chinese *kaifang* method does not raise in the Chinese mind the same idea that an equation raises in the mind of a Western mathematician. As Gauchet concludes: "Eastern thought, Western thought, each has its originality, and from each there resulted two methods, one better adapted to numerical applications, the other much richer for the development of pure algebra."

4364. Lam Lay Yong. "The Geometrical Basis of the Ancient Chinese Square Root Method". *Isis* 61 (1969), 96-102.

The author notes that traditional Chinese mathematics "encountered no difficulty in root extractions and in the solving of higher numerical equations as compared with their Western counterparts," (p. 92). When higher degree equations were encountered, they were usually approached on a "case by case" basis, but in China, as early as the Han dynasty (206 B.C. -221 A.D.), a basic method for root extractions had been devised by a method comparable to Horner's method (1819). Wang Ling and Joseph Needham, item 4367, first discussed this method and even demonstrated how to find the square roots of 55, 225 and 1, 860, 867 using the ancient Chinese procedure. Lam points out that the oldest surviving geometric diagram on which the method was presumably based is found in Yang Hui's *Xiang jie jiuzhang suanfa* (†A Detailed Analysis of the Mathematical Methods in the Nine Chapters†) of 1261. Yang Hui illustrates the method in the case of 71, 824, and shows how counting rods were used to solve the problem. Lam's paper presents a translation of the most relevant passages from Yang Hui's work, based on the version found in the *Yongle Encyclopedia* (1407). Not only does it explain the significance of the terminology used to describe root extractions, but draws comparisons with the Greek method of Theon of Smyrna for extracting square roots. Because the Greek method was basically dependent on geometric diagrams, whereas the Chinese method was more abstract, Lam suggests that Chinese mathematicians were able to generalize the square-root method to solve higher order numerical equations.

4365. Volkov, Alekseĭ [=Alexeï] Karlovich. "Ob odnom drevnekitaĭskom matematicheskom termine". (*On one ancient Chinese mathematical term.*) In *Tezisy konferentsii aspirantov i molodyh nauchnyh sotrudnikov IV AN SSSR.* (†Abstracts [of the papers delivered at] the Conference of post-graduate students and junior researchers of the Institute of Oriental Studies of the USSR Academy of Sciences†.) Vol. 1, part 1. Moscow: Nauka, 1985, 18-22.

This paper is concerned with the phrase "*yi mian ming zhi*" ("define it with/as a side") associated with in the algorithm for extraction of square roots in the *Jiu zhang suan shu* (†Nine Chapters†). The phrase describes an operation which should be performed in the case when the square root is to be extracted from an integer that is not a perfect square. Chinese and Japanese scholars have traditionally understood this verbal formula as prescribing an approximation of the square root with a common fraction. In 1983 Bai Shangshu disproved this interpretation without suggesting any alternative hypothesis. Earlier, Wang Ling and Joseph Needham (item 4367) suggested that the phrase prescribes an indefinite continuation of the procedure of extraction; however, their interpretation does not seem convincing. On the basis of commentaries on the *Jiu zhang suan shu*, Volkov suggests that the expression "*yi mian ming zhi*" means to represent the square root of N verbally as "*N zhi mian*" ("the side [of the square of the area] N"). The author considers references to several occurrences of this verbal formula in the commentaries on the *Jiu zhang suan shu*. Later, Guo Shuchun, Li Jimin, and Karine Chemla independently arrived at similar interpretations; see, for example, Karine Chemla, item 4359.

4366. Volkov, Alekseĭ [=Alexeĭ] Karlovich. "O geometricheckom proiskhozhdenii drevnekitaĭskogo metoda izvlecheniya kvadratnykh i kubicheskikh korneĭ". (†On the geometrical origin of the ancient Chinese methods of square and cubic root extraction†.) In *Istoriya i kul'tura Vostochnoĭ i Yugo-Vostochnoĭ Azii.* (†History and Culture of East and South East Asia†.) Vol. 1. Edited by S. V. Volkov. Moscow: Nauka, 1986, 172-192.

The author provides a translation of the algorithms of square and cube root extraction from the *Jiu zhang suan shu* (†Nine Chapters†) together with the commentaries of Liu Hui (fl. ca. 263) and Li Chunfeng (602-670). He argues that in both cases a geometric interpretation was used by the commentators to demonstrate the method, and that the method differs slightly from the so-called Ruffini-Horner scheme, since the binomial formula for powers 2 and 3 (interpreted geometrically) was involved.

4367. Wang Ling, and Joseph Needham. "Horner's Method in Chinese Mathematics; its Origins in the Root-Extraction Procedures of the Han Dynasty". *T'oung Pao* 43 (1955), 345-401.

This paper argues that procedures equivalent to Horner's method for solving higher order numerical equations originated in the Chinese classic text, the *Jiu Zhang Suan Shu*. In order to support this conclusion, the paper first describes the procedures followed in Horner's method, and then goes on to explain how the method was actually discovered in China. This paper is now considered to be a classic on the Chinese method of root-extraction. The conclusions of this paper, however, were recently challenged by Karine Chemla in item 4362 where she writes "I have felt it necessary to reject [the conclusion] of Needham and Wang Ling that we may find it [Horner's method] in the *Nine Chapters*," (p. 251).

Solution of Equations

4368. Chemla, Karine. "Algebraic Equations East and West Until the Middle Ages". In *Tradition and Beyond. Papers from the 7th International Conference on the History of Science in East Asia, Kyoto, 2-7 August, 1993.* Edited by Keizô Hashimoto, Catherine Jami, and Lowell Skar. Osaka: Kansai University Press, 1995, 83-89.

This paper shows that various traditions (Babylonian, Chinese, Greek) elaborated different concepts for what appear to us now as the same objects: a quadratic or cubic equation. Such an observation makes clear why and how the retrospective reading of ancient sources in modern terms cannot be sufficient to appreciate them properly. Later on, various Arabic sources are shown to have synthesized these various approaches, a process through which the modern approach to equations was formed. This process of synthesis still requires analysis as a kind of mathematical work in itself.

4369. Chemla, Karine. "Different Concepts of Equations in *The Nine Chapters on Mathematical Procedures* and in the Commentary on it by Liu Hui (3rd Century)". *Historia Scientiarum* 4 (1994), 113-137.

This paper analyzes the concept of equation as it appears in the "*fangcheng*" chapter of *The Nine Chapters*, and in the commentary on this chapter by Liu Hui (3rd century). It also describes the symbolical apparatus elaborated there to organize a world of equations. In various respects, these equations appear to be of a different nature from the quadratic equations in chapter nine of *The Nine Chapters*. Clearly, mathematical concepts that from a modern perspective are regarded as comparable were conceived as essentially different by Liu Hui. Remarkably enough, the organization of equations in the "*fangcheng*" chapter in *The Nine Chapters* bears striking similarities to the constructions elaborated by al-Khwārizmī to deal with quadratic equations in general. Similarities and differences between these Chinese and Arabic examples are discussed.

4370. Guo Shuchun. "The Numerical Solution of Higher Equations and the Tianyuan Method". In *Ancient China's Technology and Science*, Beijing: Foreign Languages Press, 1983, 111-123.

The method of solving algebraic equations (*kai fang shu*) was developed in the Song Dynasty (960-1279) into the method of extracting roots by successive additions and multiplications (*zeng cheng kai fang fa*). Related innovations made by Chinese mathematicians in this important period of Chinese mathematics, including methods for solving simultaneous higher equations, are considered in detail. The importance of a Chinese version of the Pascal triangle is also discussed. Comparisons with various Western mathematicians, including Petrus Apianus, Bézout, and Descartes are also drawn.

4371. Lam Lay Yong. "The Chinese Connexion Between the Pascal Triangle and the Solution of Numerical Equations of any Degree". *Historia Mathematica* 7 (1980), 407-424.

The conceptual development of Chinese methods for solving numerical equations, which began with procedures for extracting square and cube roots in the Han dynasty, culminated in solutions of higher order numerical equations in the 13th and 14th centuries. This paper shows how the triangular arrangement of numbers known in the West as the

Pascal triangle was used in the development of Chinese methods for the solution of equations, especially as early geometric concepts were being replaced by more algebraic ones.

4372. Lam Lay Yong. "Chinese Polynomial Equations in the Thirteenth Century". In *Explorations in The History of Science and Technology in China.* Edited by Li Guohao, et al. Shanghai: Chinese Classics Publishing House, 1982, 231-272.

This is a comparative and developmental study of contributions to polynomial equations by four Chinese mathematicians in the Song-Yuan dynasties, namely Li Ye, Qin Jiushao, Yang Hui, and Zhu Shijie. The article points out that the development of Chinese polynomial equations occurred in two parallel ways, namely in terms of the processes of forming the equations, and of the methods for solving them, both of which in turn had their own origins in the extraction of square and cube roots. Lam then goes on to explain how Jia Xian, a mathematician of the Northern Song period, established a relationship between the triangular array of numbers known in the West as the Pascal triangle, and the procedures of square and cube root extraction. The influence of this triangle on the later development of Chinese mathematics culminated in the introduction of an improved algorithmic method which could find a root to any number of decimal places of a numerical equation of any degree.

In trying to explain the equality of two quantities, Chinese mathematicians shifted from diagrammatic representations to algebraic concepts when they introduced the *tianyuan* method to represent unknown quantities. This method of representation was perfected by Li and Zhu. The pinnacle in the evolution of Chinese algebra was reached when Zhu conceived the use of the counting board to facilitate solution of systems of four polynomial equations of varying degrees in four variables.

4373. Lam Lay Yong and Ang Tian-Se. "The Earliest Negative Numbers: How They Emerged from a Solution of Simultaneous Linear Equations". *Archives internationales d'histoire des sciences* 37 (1987), 222-262.

This article presents a detailed study of the eighth chapter of the *Jiu Zhang Suan Shu* (†Nine Chapters†), entitled "Fang Cheng", focusing on the use of negative numbers. It also provides an English translation of problems 1, 2, 3, 6, 8, 10, 13, 17, and 18 of this chapter, as well as some of Liu Hui's commentaries. Having explained how Chinese mathematicians handled negative numbers within this context, the essay points out that "the Chinese not only accepted the validity of negative numbers but understood their relationships with positive ones and were able to formulate rules and to compute with them," (pp. 261-262).

4374. Lam Lay Yong and Shen Kangsheng. "Methods of Solving Linear Equations in Traditional China". *Historia Mathematica* 16 (1989), 107-122.

A survey of different methods for solving linear equations using the Chinese rod numeral system. The equations range from simple linear equations in one unknown to a set of simultaneous equations in five unknowns. Problems from a variety of classic mathematical treatises are used to illustrate the methods, especially those meant to demonstrate the positional notation used by the rod numeral system. The author notes the development of elementary algebra in China from an early period before the Christian era.

Indeterminate Analysis

4375. Ang Tian-Se. "Chinese Interest in Indeterminate Analysis and Indeterminate Equations". *Bantai xuebao* 5 (1972), 105-112.

4376. Libbrecht, Ulrich. "Indeterminate Analysis, Historical Relations Between China, Islam and Europe". In *Proceedings of the XIVth International Congress of the History of Science, Tokyo, 1974*. 311-314.

The Rule of False Position

4377. Chemla, Karine. "Reflections on the World-Wide History of the Rule of False Double Position, or: How a Loop was Closed". *Centaurus* 39 (1997), 97-120.

4378. Ma Li. "The Rule of False: Early Applications and Conjectured Transmissions". Preprint, Department of Mathematics, Chalmers University of Technology, The University of Göteborg, 1993.

4379. Vygodskiĭ, M. Y. "Proiskhozhdenie pravila dvukh lozhnykh polozheniĭ". (†The Origin of the Method of Double False Position†) *Istoriko-matematicheskie issledovaniya* 13 (1960), 231-252. In Russian.

Surveying Problems and Methods

4380. Lam Lay Yong and Shen Kangsheng. "Mathematical Problems on Surveying in Ancient China". *Archive for History of Exact Sciences* 36 (1986), 1-20.

This article reconstructs two methods of derivation used by Liu Hui in his commentaries on the *Jiu Zhang Suan Shu*, and argues that there are another two methods he probably derived in turn from those methods as well. The article holds that Liu Hui might have used all four methods respectively (or combinations thereof) to derive the results of the nine surveying problems he presents in the *Hai Dao Suan Jing*.

4381. Vogel, Kurt. "Ein Vermessungsproblem reist von China nach Paris". *Historia Mathematica* 10 (1983), 360-367.

This paper traces the history of a surveying problem from ancient China to the Latin West. The problem, which first appears in Liu Hui's *Hai Dao Suan Jing* (†Sea Island Mathematical Manual†, 3rd. century A.D.) involves, in its original Chinese form, determination of the height of a mountain or tower, where the distance between the observer and object is not passable or directly measurable. The same problem also arises in works by Indian mathematicians (Āryabhaṭa, Brahmagupta), Arabs (al-Bīrūnī), and in the Christian Middle Ages (*Geometria incerti auctoris*, Hugo de Sancto Victore), in which the examples and methods of solution are all similar. Vogel offers his own interpretation of how the various works in question may be related.

The Double Difference Method

4382. Lih Ko-Wei. "From One Gnomon to Two Gnomons: A Methodological Study of the Method of Double Differences". In *Philosophy and Conceptual History of Science in Taiwan*. (Boston Studies in the Philosophy of Science, vol. 141.) Edited by Lin Cheng-Hung and Fu Daiwie. Dordrecht: Kluwer Academic Publishers, 1993, 149-165.

This paper examines the *chong cha* method (of double differences) to elucidate the methodology adopted in terms of its "local context" in Chinese mathematics. Explaining how solar measurements with a single gnomon could be carried out, the paper then considers a number of postulates, evaluating different methods in terms of what the author terms the flat-earth postulate, the shadow ratio postulate, and the conservation of proportionality postulate. Discussion then shifts to methods involving the proportionality of two gnomons, and variations on the *chong cha* method, including *chong cha* on an inclined plane, and how Liu Hui was able to drop the shadow ratio postulate by introducing the second gnomon. The author concludes that the appraisal of historical facts depends heavily on the selection of methodologies. In trying to reconstruct the process whereby Chinese mathematicians advanced the *chong cha* method, Lih concludes that "Lacking a correct model of the earth, *chong cha* gradually moved away from the research tradition of Chinese cosmology and settled in a comfortable niche in the research tradition of Chinese mathematics," (p. 164).

Right Triangles and the "Pythagorean" Gou-Gu Theorem

4383. Ang Tian-Se. "Chinese Interest in Right-Angled Triangles". *Historia Mathematica* 5 (1978), 264-265.

Ang traces the discovery of the so-called "Pythagorean" theorem and differing views about its origins. From its earliest occurrence in an Old Babylonian cuneiform text (ca. 1900-1600 B.C.), the theorem also appears in the Vedic Sulba-sutras (ca. 800-500 B.C.), but without proof.

The first appearance of the theorem in China is found in an astronomical work, the *Zhou Bi Suan Jing* (†Classic of the Zhou Gnomon†), and the first to provide a commentary on the text was Zhao Junqing (also known as Zhao Shuang, also known as Jun Qing), who gave an algebraic version of the right-triangle theorem using quadratic equations in the 3rd century A.D. Similar proofs are later found in Bhaskara II's work in the 12th century (Ang considers the question of transmission here). Similar applications of right-triangle properties in other Chinese works, the *Jiu Zhang Suan Shu*, the *Hai Dao Suan Jing*, and the *Zhang Qiujian Suanjing*, are also discussed. Ang concludes that in the Chinese context, right-triangle methods were of interest primarily for their practical applications, largely for surveying.

4384. Lam Lay Yong and Shen Kangsheng. "Right-angled Triangles in Ancient China". *Archive for History of Exact Sciences* 30 (1984), 87-112.

This article was inspired by B. L. van der Waerden's "On Pre-Babylonian Mathematics I & II", *Archive for History of Exact Sciences* 23 (1980), 1-46. It discusses right-angled triangles in the *Zhou Bi Suan Jing* and the *Jiu Zhang Suan Shu*, as well as the commentaries on same by Zhao Shuang and Liu Hui. By reconstructing Zhao and Liu's proofs, and classifying different types of problems based on right-angled triangles, the authors argue that van der Waerden's hypothesis, i.e. that Chinese treatment of right-angled triangles can be traced back to pre-Babylonian Europe, is false.

4385. Swetz, Frank J. "Right Triangle Concepts in Ancient China: From Application to Theory". *History of Science* 31 (1993), 421-439.

This article examines accounts of right triangles of both mystical and historical origins, including the treatment of right triangles in classic Chinese mathematical texts, notably the *Zhou Bi Suan Jing*, *Jiu Zhang Suan Shu*, and *Hai Dao Suan Jing*. The author concludes that "Chinese mathematicians achieved an early and rapid development of right-triangle theory," (p. 437). Several illustrations are included, among them a diagram for determining the height of the sun by measuring the shadow of the sun at solstice, and another for the surveying of an island at sea (pp. 424, 434 respectively).

4386. Swetz, Frank J., and T. I. Kao. *Was Pythagoras Chinese? An Examination of Right Triangle Theory in Ancient China*. University Park: The Pennsylvania State University Press, 1977.

The authors note in their preface that their main purpose is to examine the evidence in ancient Chinese mathematical texts for supposing that well before Pythagoras first proved the theorem named after him concerning right triangles, that the theorem was known and had been proved in China. In order to do so, they have provided an annotated translation of the 24 problems on right triangles given in Chapter 9, the

"*Kou-ku*" ("*Gou-Gu*") chapter of the *Nine Chapters*. The translation is based on Liu Hui's version of the *Nine Chapters* as preserved in the Ming dynasty encyclopedia, the *Yongle Dadian*, and later revised during the reign of the Kang Xi emperor. Additional comments by the Tang scholar Li Chunfeng are also included (which is not the case in the edition of the *Nine Chapters* by Kurt Vogel, item 4299). Illustrations from the Qing dynasty also accompany the text. A brief concluding chapter of 7 pages fails to resolve the question of the book's title, with the authors noting that "further research will have to be conducted to resolve the basic question of this monograph," (p. 67).

4387. Wagner, D. B. "A Proof of the Pythagorean Theorem by Liu Hui (Third Century A.D.)". *Historia Mathematica* 12 (1985), 71-73.

This short note offers a diagram (a reconstruction of one attributed to Liu Hui) showing how a Chinese proof of the so-called "Pythagorean Theorem" might have been devised by the cutting up and rearrangement of the squares on the two legs of a right triangle to constitute the square on the hypotenuse. The author notes that such procedures are related to the Chinese game of "tangrams," and gives a possible reconstruction for Liu Hui's diagram.

4388. Yao Fan. (Yao Fang.) *Teorema Pifagora v drevnem Kitae*. (†The theorem of Pythagoras in ancient China†.) Moscow: VINITI, 11.04.95, dep. VINITI no. 982-B95, 10 pp.

Circle Squaring and Approximations of π

4389. He Shaogeng. "Method for Determining Segment Areas and Evaluation of π". In *Ancient China's Technology and Science*. Beijing: Foreign Language Press, 1983, 90-98.

In addition to describing Liu Hui's method for determining segment areas of the circle (263 A.D.), this article also discusses his various approximations of the value of π by inscribing regular polygons within a circle (Liu Hui used a 192-sided polygon, and then went on to obtain the area of an inscribed polygon of 3,072 sides from which he, as the author believes, evaluated π as 3927/1250, or 3.1416). Zu Chongzhi found an even better approximation for π, 355/113, and determined the "deficit value" and "excessive value" for π as: $3.1415926 < \pi < 3.1415927$. He Shaogeng then goes on to discuss later approximations for π found by the Qing dynasty mathematician Ming Antu using infinite series expansions. The article concludes with a description of the method used by Xiang Mingda (1789-1850) for finding the circumference of an ellipse, which he did in terms of power series. Although these methods fell short of the calculus, the author notes that, nevertheless, "they helped prepare Chinese mathematicians for a new era of Descartes, Newton and Leibniz."

4390. Jami, Catherine. "Une histoire chinoise du nombre π". *Archive for History of Exact Sciences* 38 (1988), 39-50.

This paper gives an annotated translation of Cen Jiangong's preface to Ming Antu's (?-1765?) *Geyuan milü jiefa* (†Quick methods for trigonometry and for determining the precise ratio of the circle†). This document presents a history of pi written in 18th-century China.

4391. Liu Dun. "A Comparison of Archimedes' and Liu Hui's Studies of Circles". In *Chinese Studies in the History and Philosophy of Science and Technology.* Edited by Fan Dainian and Robert S. Cohen. Translated by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 279-289.

Among the relatively common and familiar geometric figures, the circle is not only perfect in its symmetry, but has many obvious and practical applications, especially in astronomy. Therefore, understanding circles mathematically can be considered a rough measure of the mathematical sophistication of ancient cultures. This paper compares the work of the Greek mathematician Archimedes (287-212 B.C.) and the Chinese mathematician Liu Hui (3rd century B.C.), points out differing characteristics of Greek and Chinese mathematical systems, and suggests how the characteristic differences may be related to differing cultural traditions.

4392. Mikami, Yoshio. "The Circle-squaring of the Chinese". *Bibliotheca Mathematica* (III. Folge) 10 (1910), 193-200.

This paper discusses different values for pi obtained from antiquity down to the late Qing dynasty by Chinese mathematicians such as Chang Heng (Zhang Heng), Wang Fan, Liu Hui, Tsu Ch'ung-shih (Zu Chongzhi), Chang Yu-chin (Zhao Youqin), and Tseng Chi-hung (Zeng Jihong). The most valuable part of the paper is its explanation of the term "Chui-shu (Zhuishu)," which is the title of the now-lost book by Zu Chongzhi of the fifth century.

4393. Smeur, A. J. E. M.. "On the Value Equivalent of π in Ancient Mathematical Texts. A New Interpretation". *Archive for History of Exact Sciences* 6 no. 4 (1970), 249-270.

Section eight of this article is devoted to a Chinese mathematical text, mainly Liu Hui's *Ge Yuan Shu* (†Method of cutting the circle†). The paper points out that Liu Hui's result for the value of π is a little too large (pp. 261-262).

4394. Volkov, Alekseĭ [=Alexeï] Karlovich. "Calculation of π in Ancient China: from Liu Hui to Zu Chongzhi". *Historia Scientiarum* 4 (1994), 139-157.

This paper discusses several problems related to Liu Hui's commentary on the formula for determining the area of a circle given in the ancient

Chinese mathematical classic text, the *Jiu Zhang Suan Shu* (the †Nine Chapters on the Art of Mathematics†), as well as the determination of the value of pi ascribed to Zu Chongzhi (429-500 A.D.). Reviewed by Jami, Catherine in **MR** 96c:01014.

4395. Volkov, Alekseĭ [=Alexeï] Karlovich. "Zhao Youqin and his calculation of π". *Historia Mathematica* 24 (1997), 301-331.

The paper discusses the method used by Zhao Youqin (1271-1335?) in his treatise *Ge xiang xin shu* to confirm Zu Chongzhi's (429-500) approximate value of 355/113 for π. Zhao inscribed a square into a circle and performed an iterative procedure calculating one side of a $2n$-sided inscribed polygon for $n = 3, \ldots, 14$. Included is a biographical sketch of Zhao, who was an astronomer, mathematician, and physicist as well as a Daoist monk and alchemist. A translation of Zhao's description of his method is given in the appendix. Reviewed in **MR** 98g:01015 (author's summary).

4396. Wang Ling. "A New Suggestion on Tzu Ch'ung-Chih's Method of Finding the Value of π and its Significance in the History of Mathematics". *Papers on Far Eastern History* 16 (1977), 161-165.

The author points out that Tzu Ch'ung-Chih (Zu Chongzhi) used a value for π of 355/113, correct to six decimal places, that is the same value as used eleven centuries later by Valentinus Otto. How did Zu obtain his result? According to the author, in 263 A.D. Liu Hui, in his commentary on the *Nine Chapters*, used a polygon of 3072 sides to approximate π as $3927/1250 = 3.1416$. Liu's method, similar to the Archimedean method of exhaustion, has led some to suggest that by simply doubling the number of sides to the approximating polygon of 6144 sides will provide Zu's result. But Wang Ling cites the praise Zu received from a Tang dynasty commentator for having used a new method. This leads Wang to suggest that Zu had read Liu Hui's commentary, took his value of 3927/1250 for π, and then applied the Chinese Remainder Theorem to obtain his more accurate approximation.

4397. Zha You-Liang. "Research on Tsu Ch'ung-Chih's Approximate Method for π". In *Science and Technology in Chinese Civilization*. Edited by Chen Cheng-Yih. Singapore: World Scientific Publishing Co., 1987, 77-86.

Holds that Zhu Chongzhi probably used an interpolation method based on continued fractions and convergence to obtain his approximation of π.

Volumes of Pyramids and Spheres

4398. Fu Daiwie. "Why Did Liu Hui Fail to Derive the Volume of a Sphere?" *Historia Mathematica* 18 (1991), 212-238.

This article argues that Liu Hui's failure to derive correctly the volume of a sphere was inherent in his "heuristic"—"a powerful pattern of reasoning that enabled Liu Hui to solve many geometrical problems, but also restrained him from finding the volume of a sphere." Also considered is the approach Zu Geng (also known as Zu Gengzhi) took to the same problem. The author hopes to use both to reconstruct and elucidate "at least part of the historical structure of ancient Chinese geometry." Rather than use classification schemes of 20th-century Western mathematics, the author looks to the Chinese historical context to investigate the development of early Chinese geometrical thinking.

4399. Wagner, Donald B. "Liu Hui and Tsu Keng-chih on the Volume of a Sphere". *Chinese Science* 3 (1978), 59-79.

In this article Wagner translates a proof of the formula for the volume of a sphere written by Tsu Keng-chih (Zu Gengzhi, also known as Zu Geng) in the late 5th century A.D. The proof is quoted from a lost book in the commentary on the *Nine Chapters* by Li Chunfeng (602-670). Wagner draws comparisons with Cavalieri's methods as similar to those used by Liu Hui and Zu Gengzhi, gives a summary of Zu's proof, then a translation with commentary of problems 23 and 24 from chapter 4 of the *Nine Chapters*, along with the relevant Chinese text.

4400. Wagner, Donald B. "An Early Derivation of the Volume of a Pyramid: Liu Hui, Third Century AD". *Historia Mathematica* 6 (1979), 164-188.

The *Jiu Zhang Suan Shu* (the *Nine Chapters*) gives practical problems and states the algorithm for their solution, but without offering any explanations. A commentary by Liu Hui (3rd century) explains each algorithm, which in turn satisfies many of the criteria expected of proofs. The author translates and discusses Liu Hui's explanation for the formula for the volume of a particular kind of pyramid.

4401. Volkov, Alekseĭ [=Alexeï] Karlovich. "Ob infinitezimal'nom metode vychisleniya ob"ema piramidy". ("On the infinitesimal method of the calculation of the volume of a pyramid".) In *19-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov.* (†19th Scientific Conference "Society and State in China." Abstracts of papers†.) Vol. 1. Moscow: Nauka, 1988, 143-146.

The paper concerns the method of calculation of the volume of a pyramid by Liu Hui (fl. ca. 263) as given in his commentary on problem 15, chapter 5, of the *Jiu zhang suan shu* (†Nine Chapters†). The author focuses on the "infinitesimal" passage in the inference, treated before him by several Asian scholars as well as by D. B. Wagner, item 4400. Wagner suggested a new interpretation based on the translation of the key phrase dealing with the numerical parameters of the pyramid which is to be dissected indefinitely. The phrase involves terms which were identified by Wagner as related to a "natural philosophy" of the ancient Chinese. Volkov argues that the terms were also used elsewhere by Liu Hui to refer to small common decimal fractions. Interpreted in this way, the phrase makes Liu Hui's demonstration of the method mathematically plausible.

The Chinese Cavalieri Principle

4402. Lam Lay Yong and Shen Kangsheng. "The Chinese Concept of Cavalieri's Principle and its Applications". *Historia Mathematica* 12 (1985), 219-228.

In the third century, while attempting to derive the volume of a sphere, Liu Hui applied a principle similar to Cavalieri's to determine the ratio of the volumes of a sphere and a solid circumscribing the sphere. The solid was formed by the intersection of two perpendicular cylinders circumscribing the sphere. Liu Hui left unresolved the problem of finding the volume of this figure. In the late fifth or early sixth century, Zu Geng (also known as Zu Gengzhi), applying the same principle as Liu Hui and Cavalieri, solved the problem and was thus able to derive the correct volume of the sphere. The influence of Zu Geng's methods on later Chinese mathematics is considered in the last part of the article, which includes discussion of Mei Wending (1633-1721) and Xu Youren (1800-1860).

The Chinese Remainder Theorem

4403. Li Wenlin and Yuan Xiangdong. "The Chinese Remainder Theorem". In *Ancient China's Technology and Science*. Beijing: Foreign Languages Press, 1983, 99-110.

This paper begins with a description of a number of traditional mathematical games and folk rhymes that turn out to be mnemonic devices for remembering arithmetic procedures. The authors present one for the solution of a famous problem that appears in the *Sunzi suanjing* (†Master Sun's Mathematical Manual†, 4th century). The problem in question is then interpreted in terms of simultaneous indeterminate equations. The article goes on to analyze the *Sunzi* method for solving indeterminate equations, for which the authors also offer a generalized version. They go on to investigate the connection between the remainder theorem and the astronomical problems for which solutions of linear congruences were needed given recurring calendrical cycles. They conclude with a discussion of Chinese contributions to linear congruences, including Qin Jiushao's *dayan* method, which is then compared with methods devised in the West by Fibonacci, Euler and Gauss. A concluding paragraph notes work in India also related to linear congruences, notably by Brahmagupta (7th century) and Mâhavîra (9th century).

4404. Mahler, K. "On the Chinese Remainder Theorem". *Mathematische Nachrichten* 18 (1958), 120-122.

A primarily mathematical discussion of the method of solving systems of linear congruences: $x \equiv r_i \pmod{m_i} \quad (i = 1, 2, \ldots, k)$, when the moduli are relatively prime in pairs. This, the author points out, is a method used as early as the Chinese mathematical classic texts, the *Sunzi Suanjing* and the *Zhang Qiujian Suanjing*. It was also used by the astronomer Yi Xing (682-727). This note attempts to reproduce the mathematical content of the ancient Chinese method for dealing with the more general case when the moduli m_i are not prime in pairs, a method very different Mahler points out from the one to be found in C. F. Gauss's *Disquisitiones Arithmeticae*.

4405. Shen Kangsheng. "Historical Development of the Chinese Remainder Theorem". *Archive for History of Exact Sciences* 38 (1988), 285-305.

The author traces the development of the Chinese Remainder Theorem in ancient China, India, Central Asia, and Western Europe, pointing out the similarities and differences between the methods of solving remainder problems developed in these different places.

4406. Wang Ling. "The Date of the *Sun Tzu Suan Ching* (= *Sunzi suanjing*) and the Chinese Remainder Theorem". In *Proceedings of the 10th International Congress on the History of Science, 1962*. Vol. 1. Paris: Hermann, 1964, 489-492.

On the Mathematical Manuscripts from Dunhuang

4407. Libbrecht, Ulrich. "Mathematical Manuscripts from the Tunhuang Caves". In *Explorations in The History of Science and Technology in China*. Edited by Li Guohao, et al. Shanghai: Chinese Classics Publishing House, 1982, 203-229.

Concerns six mathematical manuscripts found in the caves of Tunhuang (Dunhuang), Gansu, and Turfan (Tulufan), Xinjiang, by Paul Pelliot and Sir Aurel Stein respectively, which are numbered as Pelliot 2490, 2667, 3349, and Stein 19, 930, and 5779, respectively. The paper suggests that the value of these manuscripts lies in the details they provide related to metrology and decimal values, and on mathematical terminology in general.

4408. Martzloff, Jean-Claude "Notice no. 3349". In *Catalogue des Manuscrits Chinois de Touen-Houang, Fonds Pelliot Chinois de la Bibliothèque National*. Vol. 3 (1983). Edited by Michel Soymié. Paris: Éditions de la Fondation Singer-Polignac, 283-285.

4409. Morgan, Carole. "Les 'Neuf Palais' dans les manuscrits de Touen Houang [Dunhuang] ". In *Nouvelles Contributions aux Etudes de Touen-Houang*. Sous la direction de Michel Soymié. Geneva: Droz, 1981, 251-260.

On Logic

4410. Graham, A. C. *Later Mohist Logic, Ethics and Science*. Hong Kong: The Chinese University Press, 1978.

This book is divided into three parts. The first part is an introduction to Moist (= "Mohist") philosophy, including historical background, later Moist logic, ethics, and science. The second part discusses textual problems, Chinese grammar, and eight key words, as well as forty technical terms, besides giving the English translation of the original text. The third and last part is devoted to appendices, including the Chinese original text of *Mozi*, chapters 40 to 45.

4411. Greniewski, Henry K., and Olgierd Wojtasiewicz. "From the History of Chinese Logic". *Studia logica* 4 (1956), 241-243.

From the 6th to mid-3rd century B.C., there was an "extraordinary outburst of philosophical thought in China." The School of Names and the so-called Dialecticians, so the authors argue, were "hampered by peculiarities of the old Chinese language" which lacked morphology and did not formally differentiate between parts of speech. All this rendered formal reasoning, they maintain, very difficult. This paper dissects a problem raised by Kung-Sun Lung [=Gongsun Long] (fl. 4th century B.C.), an outstanding representative of the Dialecticians, who commented on the famous "white horse paradox," which the authors relate to the larger problem of "universals" discussed in terms of the logic of the algebra of sets, upon which they conclude that Kung-Sun Lung's text "does not seem to form a coherent deductive proof" (p. 243).

4412. Hu Shih [=Hu Shi]. *The Development of the Logical Method in Ancient China*. Shanghai: Oriental Book, 1922.

This book is a modification of the author's dissertation presented to Columbia University in 1917, and is the first work in any language devoted to the study and development of logical methods in China in the period from 600 B.C. to 210 B.C. The first part of the book presents the historical background with a description of the political, social and intellectual conditions which prevailed during this period. The second part discusses Confucian logic, in particular the *Yi Jing* (†Book of Changes†). The major part of the book is devoted to a discussion of Moist logic, including the founder of this school Moh Tih (Mo Di), as well as the logical theories of the philosophers Hui Sze (Hui Shi), and Kung-Sun Lung (Gongsun Long). The last part discuses the relation between theories of natural evolution and the logic of Chuang Tze (Zhuangzi) and Hsun Tze (Xunzi). The book includes an epilogue which presents a long passage from the *Shi Ji* (†Records of a Historian†) by Sze-Ma Chien (Sima Qian).

4413. Lau, D. C. [=Lau Dim Cheuk] "Some Logical Problems in Ancient China". *Proceedings of the Aristotelian Society* 53 (1953), 189-204.

This article focuses on the logical problems found in chapter forty-five of the *Mo Tzu* (*Mozi*). Beginning with a general introduction of the four logical methods: analogy, parallel, precedent, and extension, the author gives his translation of all the problems found in the chapter. After pointing out the nature of the arguments used in these problems, the author goes on to examine how Mohists used their logical methods to argue with their opponents. In the last section of the article, the author gives his own opinion about the difficulties of analyzing the reasoning of the ancient Chinese due to the Chinese language's lack of grammatical determination in nouns and verbs, among others.

4414. Maspero, Henri. "Note sur la Logique de Mo-Tseu et de son école". *T'oung Pao* 25 (1928), 1-64.

This article is devoted to a study of reasoning by example in the school of Mozi. It includes examination of "false reasoning" as well as the theory of knowledge espoused by the Mozi school.

On Limits, Infinity, and Infinitesimals

4415. Chemla, Karine. "Méthodes infinitésimales en Chine et en Grèce anciennes: les limites d'un parallèle". In *Le labyrinthe du continu*. Edited by H. Sinaceur and J. M. Salanskis. Berlin: Springer, 1992, 31-46.

This paper was presented at a conference on the "continuous" held in September 1990 in Cerisy (France). It is devoted to a comparative study of treatments of infinity in ancient Greek and Chinese mathematics. For this purpose, proofs of the formula for the volume of a pyramid as they are given in Liu Hui's commentary on the *Nine Chapters* and in Euclid's *Elements* are compared. First, a new interpretation is given for Liu Hui's proof that does not require an emendation of the original text. How the proof brings into play the fundamental transformation "with the excess, fill up what is empty" is also explained. It is then shown that the proof follows a pattern that is the same whenever Liu Hui deals with an infinite number of steps. The use of the so-called "method of exhaustion" has the same status in Euclid's text. Comparison with Euclid's treatment brings to light the fact that Liu Hui makes use of actual infinity whereas Euclid only makes use of potential infinity. Euclid, however, always proceeds by *reductio ad absurdum* whereas Liu Hui always proceeds by direct reasoning. Moreover, it is shown that Liu Hui departs in such cases from all known pre-Eudoxian mathematicians in evaluating the decrease of the remainder. Concepts of infinity cannot be separated from modes of reasoning, and this paper concludes by hypothesizing why *reductio ad absurdum* proofs may not have suited Chinese mathematical practice.

4416. Chen Cheng-Yih. "A Comparative Study of Early Chinese and Greek Work on the Concept of Limit". In *Science and Technology in Chinese Civilization*. Edited by Chen Cheng-Yih. Singapore: World Scientific Publishing Co., 1987, 3-52.

Examines Ancient Greek and Chinese mathematical concepts such as continuity, infinite divisibility, and the infinitely small, and discusses how these all contribute to the understanding of the concept of limit. Appendix I gives a chronological summary of dates and events in the *Zhou Bi Suan Jing*, the *Jiu Zhang Suan Shu*, and *Elements* (pp. 29-34). Appendix II gives the dissection proof for the Gou-Gu theorem (Pythagorean theorem) as found in the *Zhou Bi Suan Jing* (pp. 35-44).

4417. Horng Wann-Sheng. "How Did Liu Hui Perceive the Concept of Infinity: A Revisit". *Historia Scientiarum* 4 (1995), 207-222.

In their attempts to deal rigorously with the problem of dividing the circumference of the circle, ancient Chinese mathematicians were forced to confront the question of its infinite divisibility. The author argues that this is one way in which the word "infinite" may have come into play in the mathematical practice of both the ancient civilizations of Greece and China. In this article Horng Wann-Sheng specifically examines Liu Hui's conception of infinity and the part it played in his own attempts to approximate the area of the circle and volume of a pyramid. Emphasis, the author says, is given to "how [Liu Hui] used the method of limits." What Liu Hui may have learned from the Moists (Mo jia), from the Legalists (*fa jia*), and Sophists of the pre-Qin period is also considered. The author concludes that Liu Hui may have misunderstood what the Moists meant by such technical terms as "*Duan*," "*Hou*," "*Ci*," and "*Qu*," but that he was nevertheless greatly influenced by Moist thought on the subject of infinity, as reflected in his principle of exhaustion. Horng maintains that Liu Hui was primarily influenced by the Moists not only in his methodology, but also in his epistemology.

4418. Lloyd, Geoffrey. "Finite and Infinite in Greece and China". *Chinese Science* 13 (1996), 11-34.

This article compares how the Chinese and the Greeks thought about and dealt with concepts of finite and infinite in the period from circa 300 B.C. to circa 200 A.D. The author, at the outset, presents his own criteria for pursuing comparative studies of history of science in general, emphasizing the importance of studying the relation "between the science produced and the society which produced it," (p. 12).

The first part of the article reviews common assumptions about the sharp contrasts between ancient China and Greece concerning these two concepts, which hold that the Greeks "tolerated, and even cultivated, the infinite in a whole lot of contexts where the Chinese either deliberately excluded it or, more often, never even considered it," (p. 13). In the second part, the author goes on to discuss other conventional views emphasizing similarities in approach to the finite and the infinite in ancient Greece and China.

In the third and last part, the author points out that there were diverse views on the finite and infinite in both ancient China and Greece, and no orthodoxy at all. The best way to understand these differences is to examine "the aims, presuppositions and interactions of Greek, and Chinese, thinkers and . . . the nature of the philosophical exchanges cultivated in each society," (p. 12).

On Proofs, Demonstrations, and Methods in Ancient Chinese Mathematics

4419. Berezkina, Èl'vira Ivanovna "Antichnye matematicheskie metody v Kitae". (†Ancient mathematical methods in China†.) *Organon* 4 (1967), 105-107.

4420. Berezkina, Èl'vira Ivanovna "O matematicheskikh metodakh drevnikh" (†On mathematical methods of the ancients†.) In *Istoriya i metodologiya estestvennykh nauk.* (†History and methodology of the natural sciences†.) Moscow: Moscow State University Press, 1971, 172-185.

4421. Berezkina, Èl'vira Ivanovna "O matematicheskikh metodakh drevnikh. bukval'naya geometriya i teorema Pifagora". (†On mathematical methods of the ancients: the "literal" geometry and the Pythagorean theorem†.) In *Istoriya i metodologiya estestvennykh nauk.* (†History and methodology of the natural sciences†.), 16, Moscow: Moscow State University Press, 1974, 36-50.

4422. Berezkina, Èl'vira Ivanovna "O razvitii matematicheskikh metodov v drevnosti". (†On the development of the mathematical methods in ancient times†.) In *Metodologicheskie problemy razvitiya i primeneniya matematiki.* (†Methodological problems of the development and application of mathematics†.) Moscow: Academy of Sciences of USSR Press, 1985, 187-193.

4423. Chemla, Karine. "Résonances entre démonstration et procédure. Remarques sur le commentaire de Liu Hui (3° siècle) aux *Neuf Chapitres sur les Procédures Mathématiques* (1° siècle)". In *Regards obliques sur l'argumentation en Chine.* Edited by Karine Chemla. (*Extrême-Orient, Extrême-Occident* 14.) Saint-Denis: Presses Universitaires de Vincennes, 1992, 91-129.

This paper aims at bringing to light some characteristics of Liu Hui's way of proving (3rd century) the correctness of the algorithms contained in the mathematical classic the *Nine Chapters.* First, it is shown that, whether the algorithms deal with arithmetical or geometrical topics, the proofs always aim at identifying basic fundamental patterns of change underlying the algorithms. The first example given shows how the proofs for the algorithms given to add fractions or to solve systems of linear equations reveal that the same fundamental algorithm accounts for their correctness. The second example gives a new interpretation of the way in which Liu Hui proves the correctness of the algorithm to compute the volume of the pyramid. This new interpretation shows that the fundamental operation: "with the excess, fill up the void," also underlies this algorithm. The last part of this paper offers a new interpretation of the "procedure of the positive and the negative," which completes the algorithm to solve systems of linear equations. This new interpretation helps to reveal the formal relationships between the geometrical context of the volume of the pyramid and the extension of this last algorithm.

4424. Chemla, Karine. "What is at Stake in Mathematical Proofs from Third Century China?" *Science in Context* 10 (2) (1997), 227-251.

In order to highlight speculative trends specific to the mathematical tradition which developed in China, the paper analyses an excerpt of Liu Hui's commentary (third century) to the mathematical classic, *The Nine Chapters on Mathematical Procedures*, which arguably contains a proof. It is shown that the three following problems cannot be dissociated one from the other: 1. To discuss how the ancient text should be read. 2. To describe the practice of mathematical proof to which this text bears witness. 3. To bring to light connections that it demonstrates were established in China between philosophy and mathematics. To this end, the paper makes precise its use of the word "proof" and outlines a program for an international history of mathematics proof. It describes in which sense the text conveys a proof and shows how it simultaneously fulfils algorithmic ends: it brings to light a formal pattern which appears to be fundamental for both mathematics and other domains of reality. The interest in transformations that, at that time, mathematical writings demonstrate in China seems to have been influenced by philosophical developments based upon *The Book of Changes (Yijin)*, which the excerpt quotes. This quotation within a mathematical context enables the author to suggest an interpretation for a rather difficult philsophical statement.

4425. Crossley, J. N., and A. W. C. Lun. "The logic of Liu Hui and Euclid as Exemplified in Their Proofs of the Volume of a Pyramid". *Philosophy and the History of Science. A Taiwanese Journal* 3 (1994), 11-27.

The authors compare the logic employed in Euclid's *Elements* with that applied in the *Jiu Zhang Suan Shu* (†Nine Chapters†). They note that while previously it has been said that Chinese mathematics was algorithmic and practical, as opposed to the logical and theoretical approach exemplified in the West by Euclid's axiomatic mathematics, that Euclid nevertheless uses logic which either is (or could be) "as constructive as that of Liu Hui and has a number of points of contact even thought the traditions are very different."

4426. Cullen, Christopher. "How can we do the comparative history of mathematics? Proof in Liu Hui and the *Zhou Bi*". *Philosophy and History of Science. A Taiwanese Journal* 4 (1995), 59-94.

Responding to an earlier article by J. W. Crossley and A. W. C. Lun, item 4425, Cullen is concerned about the use they make of the word "proof": "While they are clear that Liu Hui and Euclid constructed 'proofs' in different ways, they appear to find nothing problematic in using the same English word to describe the activities of both ancient writers." Cullen argues that greater caution is necessary. He considers the extent to which the word "proof" is appropriate in talking about Liu Hui's mathematical commentaries on the *Jiu Zhang Suan Shu* (†Nine Chapters on the Mathematical Art†) and the even earlier Han dynasty text, the *Zhou Bi Suan Jing* (†Mathematical Classic of the Zhou Gnomon†).

4427. Dauben, Joseph W. "Ancient Chinese Mathematics: The *Jiu Zhang Suan Shu* versus Euclid's *Elements*. Aspects of Proof and the Linguistic Limits of Knowledge". Chandrasekhar Memorial Issue, *International Journal of Engineering Science* 36 (1998), 1339–1359.

This article examines the basic question of why Chinese mathematics developed as it did, especially with respect to the terms on which Chinese mathematicians argued the correctness of their results and the nature of the proofs offered in such basic works as the classic text, the *Nine Chapters*. Special attention is focused here on linguistic aspects of Chinese logic, including issues of entification and counterfactual reasoning with respect to the Chinese linguistic arsenal for devising proofs, either in everyday discourse, or in the language of mathematics.

4428. Martzloff, Jean-Claude. "Quelques Exemples de Démonstrations par dissections en Mathématiques Chinoises". *Sciences et Techniques en Perspective* 21 (1992), 1-20.

4429. Mei Rongzhao. "Mathematical Formalism in Ancient China". In *Science and Technology in Chinese Civilization*. Edited by Chen Cheng-Yih, Roger Cliff, and Chen Kuei-Mei. Singapore: World Scientific Publishing Co., 1987, 53-75.

This article argues that ancient Chinese mathematics has its own forms of proofs and formalism. The major arguments are that 1) some descriptions in the *Mo jing* and *Jiu Zhang Suan Shu* are based on definitions; 2) Liu Hui and Zhu Congzhi, as well as the latter's son Zu Geng (also known as Zu Gengzhi), along with mathematicians of the Song-Yuan period (like Jia Xian, Shu Shijie, and Li Ye (also known as Li Zhi)) certainly used proofs. A brief note on the Greek axiomatic system and its introduction into China is also given.

4430. Siu Man-Keung. "Proof and Pedagogy in Ancient China: Examples from Liu Hui's Commentary on the *Jiu Zhang Suan Shu*". *Educational Studies in Mathematics* 24 (1993), 345-357.

4431. Volkov, Alekseĭ [=Alexeĭ] Karlovich. "O dokazatel'stve v drevnekitaĭskoi matematike". (†On proof in ancient Chinese mathematics†.) In *15-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov.* (†15th Scientific Conference "Society and State in China." Abstracts of papers†.) Vol 1. Moscow: Nauka, 1984, 101-104.

The author argues that Liu Hui (fl. ca. A.D. 263) in his commentaries on the *Jiu Zhang Suan Shu* (†Nine Chapters on the Art of Mathematics†) extensively uses the method of "demonstration with examples" or "analogical reasoning." On the basis of the analysis of Chapter 5 of the treatise devoted to the computation of volumes, he shows that even though Liu Hui operates with simplified models of the solid figures in order to prove the correctness of the algorithms found in the treatise, his proofs remain valid for the general case as well. Moreover, Volkov notes that Liu Hui, in one case, criticizes a "proof" valid in a special case but not generally valid, and provides instead a generally valid one (introduced as before with a simplified model). The author remarks that the reasoning strategy of Liu Hui is the reduction of complex cases to simpler ones, even though his reductions do not necessarily correspond to the order of the problems of the chapter. Volkov suggests that this "non-linear" disposition of material was influenced by general principles that guided construction of ancient Chinese texts.

4432. Volkov, Alekseĭ [=Alexeĭ] Karlovich. "Dokazatel'stvo v drevnekitaĭskoi matematike". (†Proof in ancient Chinese mathematics†.) In *Metodologicheskie problemy razvitiya i primeneniya matematiki.* (†Methodological problems of the development and application of mathematics†.) Moscow: Academy of Sciences of USSR Press, 1985, 200-206.

The lack of an axiomatic method has prompted some modern historians of science to consider Chinese mathematics as an "empirical" discipline without criteria of strictness and a notion of proof. The author suggests that a more reasonable way to compare the Chinese mathematical tradition with ancient Greek "Euclidean" mathematics should involve a consideration of the social environment in which both disciplines were conceived and perpetuated. Volkov believes that in both cases mathematical knowledge originated within the framework of particular social bodies which can conventionally be called "schools." Each school dealt with a variety of mathematical objects conceived together with their "properties," some of which were accepted as "self-evident" by all members of the school. Thus the attribution of a property as "self-evident" was determined by cultural and social premises. Moreover, the way of constructing "proofs" depended to a large extent on socially adopted practices of "persuasive discourses," which in the case of ancient China, unlike ancient Greece with its axiomatic method, included analogical reasoning and demonstration by example.

4433. Wagner, Donald Blackmore. *Proof in Ancient Chinese Mathematics: Liu Hui on the Volumes of Rectilinear Solid*. Thesis presented at the University of Copenhagen, 1975.

Reasoning and Proofs by Analogy

4434. Volkov, Alekseĭ [=Alexeï] Karlovich. "O metode analogii v drevnekitaĭskoi matematike". (†On the method of analogy in ancient Chinese mathematics†.) In *18-aya Nauchnaya Konferentsiya "Obshchestvo i Gosudarstvo v Kitae." Tezisy dokladov.* (†18th Scientific Conference "Society and State in China." Abstracts of papers†.) Vol. 1. Moscow: Nauka, 1987, 113-117.

The author provides a formal tool for dealing with geometrical objects generated by analogy. He demonstrates that several methods of Liu Hui (fl. ca. 263) and Zhao Shuang (fl. ca. the 3rd century) involving "geometrical algebra" and conventionally considered as fairly distinct can be considered as related to one and the same basic geometrical pattern.

4435. Volkov, Alekseĭ [=Alexeï] Karlovich. "Analogical Reasoning in Ancient China. Some Examples". In *Regards obliques sur l'argumentation en Chine*. Edited by Karine Chemla. (*Extrême-Orient, Extrême-Occident* 14.) Saint-Denis: Presses Universitaires de Vincennes, 1992, 15-48.

The author provides several examples of the use of "analogical reasoning" from ancient Chinese treatises of Mengzi and Shuo yuan. He briefly discusses a possible formal representation of analogical inference and goes on to discuss several examples from the mathematical treatise *Jiu Zhang Suan Shu* and the commentaries of Liu Hui, in particular those related to the calculation of volumes.

Mathematics in the Song-Yuan Dynasties (960-1368)

4436. Brenier, Joël. "Notation et optimisation du calcul des grands nombres en Chine: Le cas de l'échiquier de go dans le *Mengqi bitan* de Shen Gua (1086)". In *Nombres, astres, plantes et viscères: Sept essais sur l'histoire des sciences et des techniques en Asie orientale*. Edited by Isabelle Ang and Pierre-Étienne Will. Paris: Institut des Hautes Études Chinoises, 1994, 89-111.

The author discusses the problem of the expression of extremely large numbers in Chinese, as an introduction to a note in the *Mengqi bitan* which is the topic of this paper and in which Shen Gua commented on a problem he attributed to Yixing: to find the number of possible configurations on a go board. This required that Shen Gua write down a number composed of 173 digits, in decimal notation. To do so, Shen Gua discussed how one could establish such a number in the best way possible and how one could record it. Brenier reviews all systems devised in China for writing down such large numbers and analyzes Shen Gua's note within this context.

4437. Chemla, Karine. *Étude du livre "Reflets des mesures du cercle sur la mer" de Li Ye*. Doctoral Thesis, 3rd cycle, Mathematics, University of Paris XIII, 1982.

This thesis is devoted to Li Ye's *Ceyuan Haijing* (1248). Its two parts each deal with one of the two main parts of this 13th-century mathematical treatise devoted to the use of polynomial algebra to solve geometrical problems. All the geometrical problems contained in the book bear on the same drawing, the characteristics of which are first analyzed. It is shown to refer to one of Liu Hui's proofs (3rd century) of the algorithm given in the *Nine Chapters* to compute the diameter of a circle inscribed in a right-angled triangle. Chemla first deals with a compendium containing 170 formulas related to the drawing and placed at the beginning of the book. The language in which the formulas are written is analyzed in considerable detail: it is shown to be such that no ambiguity remains in the statement of formulas: specificators (a special resource of the Chinese language) are used twice as parentheses would be in modern mathematical notations. Parallel sentences are frequently used in ancient Chinese written sources, and Chemla shows how Li Ye used them to express mathematical meanings when parallel formulas and parallel sets of formulas follow each other. The mathematical meanings conveyed by these parallelisms are, in their turn, the topic of some developments within parts of the compendium itself. Parallelism again is shown to govern part of the 170 problems. After a brief introduction of the basic knowledge necessary to situate the book in the history of mathematics in China, the language Li Ye used to deal with problems is analyzed. Li Ye gave the solution for each problem in two parts: the method (*fa*) and details of the method (*cao*). Chemla shows that the 170 problems all display the same hidden relationship between the "method" and the "details of the method." This relationship implies that Li Ye performed polynomial computations not only with numbers, but also with characters. This brings to light developments that have not previously been appreciated about the history of mathematics in China, and enables Chemla to offer some hypotheses about how Li Ye can be appreciated with respect to the sources he mentioned. In turn, this allows Chemla to reconstruct some of the algorithms Li Ye used to compute with polynomials on the counting board.

4438. Chemla, Karine. "Equations with General Coefficients in the *Ce Yuan Hai Jing*". In *Cahiers du Séminaire de Rennes: Science, Technique, Société*. Publications de l'Institut de Recherche Mathématique de Rennes. Fascicule II: Science, Histoire, Société. Université de Rennes, 1985, 23-30.

This paper briefly presents the main result of the second part of the author's thesis on Li Ye's *Ceyuan haijing* (1248). Li Ye gave the solution of each problem (a total of 170) in two parts: the method (*fa*) and the details of the method (*cao*), all of which display the same hidden relationship between the “method” and “details of the method.” This relationship implies that Li Ye performed polynomial computations not only with numbers, but also with characters. The author moreover describes the parallelism between the texts of problems and the way in which Li Ye used them to express mathematical meanings, in the course of which she highlights developments that have not been previously appreciated for the history of mathematics in China.

4439. Chemla, Karine. “Du parallèlisme entre énoncés mathématiques, analyse d'un formulaire en Chine au XIIIe siècle”. *Revue d'Histoire des Sciences* 43 (1990), 57-80.

The question of how to handle parallel sentences in order to describe the content of a classic Chinese mathematical text is addressed here, using the case of Li Ye's *Sea Mirror of the Circle Measurements* (1248). Parallelism is shown to be pervasive in the organization of this work, reflected primarily in the symmetry of a drawing on which the basic argument bears. As the terminology chosen by Li Ye has a structure which is itself similar to the mathematical structure of the situation, any parallelism between formulas reflects an analogy between the situations that they describe. The paper shows that groups of formulas when considered together reflect a mathematical characteristic of the behavior of various formulas with respect to this symmetry. Moreover, by analyzing systematically the parallelisms between various formulas grouped together by Li Ye, one can discover new symmetries that are mathematically more interesting and that Li Ye can be shown to have used in his elaboration of the analogies in question.

4440. Gauchet, L. “Note sur la Trigonométrie Sphérique de Guo Shoujing”. *T'oung Pao* 18 (1917), 151-174.

In ancient Chinese texts one encounters the *tianyuan* algebra and the *kai fang* method for the solution of equations. What was the role of these two methods in Chinese mathematics? Examining exercise books, it seems the answers were chosen in advance, and there is nothing to indicate that real problems or more complex examples were treated by means of these methods. In this context, the author finds the works of Guo Shoujing (1231-1316) especially interesting. Well-known for his astronomical work on the Shou Shi Li calendar, which he developed and which was used from 1281 until 1367, Guo lived in the period when the *tianyuan* method flourished. The author discusses how Guo used the *tianyuan* and *kai fang* methods to solve real problems arising from astronomy.

4441. Hoe, Jock. *A Problem in the Siyuan yujian: The Jade Mirror of the Four Unknowns.* Hamilton, New Zealand: University of Waikato: Waikato University China Papers (2). Proceedings of the First New Zealand International Conference on Chinese Studies, 1972.

4442. Hoe, Jock. *L'algèbre chinoise à la fin du XIIIe siècle à travers l'étude des systèmes d'équations-polynômes traités par Zhu Shìjié dans son livre 'Le Miroir de jade des quatre inconnues: Siyuan Yujian' de 1303.* Thèse pour le doctorat de Spécialité en Etudes Extrême-Orientales, Université de Paris VII, 1976.

Hoe's thesis begins with a detailed description of Chinese algebra, including the *Tian Yuan* method for solving systems of equations with as many as four unknowns. Chapter 2 explains in detail Zhu Shijie's algorithm and methods, including the special notation he used which was largely responsible for the subsequent failure of Chinese mathematics to develop further, which prevented development of a general algebraic notation of greater flexibility. Chapter 3 presents the mathematical content of the work. Appendix I translates the 284 problems of Zhu's text into modern symbolic terminology (pp. 1-153); Appendix II presents a translation in "semi-symbolic" terminology, pp. 154-348; Appendix III provides the Chinese text, pp. 349-526.

Libbrecht, (item 4454) while praising Hoe's mathematical exposition, nevertheless faults the lack of any contextual analysis, noting that even the connection of Zhu Shijie's *Siyuan Yujian* to his other works, or to other works of the Song period, are not described, nor is there sufficient exploration of the wider context of Chinese mathematics in particular, or the comparison of Zhu Shijie's accomplishments with mathematical developments elsewhere in the world. As Libbrecht notes, the value of Chinese knowledge of how to solve non-linear simultaneous equations, handled so masterfully by Zhu Shijie, "cannot be elucidated fully without comparing medieval European, Islamic and Indian algorithms," (p. 67).

4443. Hoe, Jock. "Zhu Shijie and his Jade Mirror of the Four Unknowns". In *History of Mathematics. Proceedings of the First Australian Conference*, (November 6–7, 1980), Clayton, Victoria, Australia: Department of Mathematics, Monash University, 1981, 1-24.

4444. Hoe, John [Jock]. *Les systèmes d'équations-polynomes dans le Siyuan Yujian (1303).* Paris: College de France, Institut des Hautes Études Chinoises, 1977, 341 pp.

This monograph is the same as Hoe, item 4442, except that it does not include the very extensive appendixes of his thesis.

4445. Holzman, Donald. "Shen Kua [Shen Gua] and his *Meng-ch'i pi-tan* [*Mengqi Bitan*]". *T'oung Pao* 46 (1958), 260-292.

The 1950s witnessed increased interest in Shen Kuo (also known as Shen Gua) and his *Meng Qi Bi Tan*. Besides Joseph Needham's *Science and Civilization in China* (Cambridge University Press, 1953), the Chinese historian Hu Tao-ching (Hu Daojing) published his two volume *Meng Qi Bi Tan Jiao Zhen* (Shanghai: Shanghai Chu Ban Gong Shi, 1956). Holzman's paper is another contribution. The paper is divided into two parts: the author presents his own accounts of Shen Kuo's life and work while making some comments on recently-published works on the subject (particularly those of Hu).

4446. Kong Guoping. "Ceyuan Haijing: A Constructive System of Mathematics". In *Tradition and Beyond. Papers from the 7th International Conference on the History of Science in East Asia, Kyoto, 2-7 August, 1993.* Edited by Keizô Hashimoto, Catherine Jami, and Lowell Skar. Osaka: Kansai University Press, 1995, 461-467.

4447. Lam Lay Yong. "On the Existing Fragments of Yang Hui's *Hsiang Chieh Suan Fa* [*Xiangjie suanfa*]". *Archive for History of Exact Sciences* 6 (1969), 82-88.

Concerns the triangular arrangment of the coefficients of the powers of a binomial (known as Pascal Triangle) and six problems in the *Xiangjie suanfa*, which is lost but fragments of which survive in the *Young Lo Da Tien* [*Yong Le Da Dian*] and the *Zhu Jia Suan Fa*.

4448. Lam Lay Yong. "The *Jih Yung Suan Fa* [*Riyong suan fa*]: an Elementary Textbook of the Thirteenth Century". *Isis* 63 (1972), 370-383.

The *Riyong suan fa* (†Arithmetical Methods for Daily Use†), written in 1261, is one of Yang Hui's earliest works. A simple arithmetic textbook meant to cover mathematics for "daily use," it was also intended to "instruct the young in observation and practice." It is of value historically because it covers in detail the methods of multiplication and division, and because it includes the most extensive collection of the various methods used. The work consists of 66 problems augmented by solutions and diagrams. Among methods discussed: the additive method of multiplication, the subtractive method of division, problems of converting decimal fractions of weight and length, as well as simple linear equations. Although the book is no longer extant, fragments have been collected by Li Yan; altogether, ten problems with their solutions are partially translated and explained here.

4449. Lam Lay Yong. *A Critical Study of the Yang Hui Suan Fa, a Thirteenth-Century Mathematical Treatise*. Singapore: Singapore University Press, 1977. Reviewed by Hoe, Jock, *Annals of Science* 39 (1982), 491-504.

This important contribution to our understanding of 13th-century Chinese mathematics presents the first complete translation of one of the most important works of the Southern Song dynasty, the *Yang Hui Suan Fa* (†Yang Hui's Methods of Computation†), which is actually a combination of three texts written by Yang Hui in 1274–1275. The first 185 pages provide the translation of Yang Hui's three works (totaling seven chapters); pp. 193-348 comprise the commentary, which explains and analyzes in detail the mathematical methods and procedures Yang Hui used. Ulrich Libbrecht (item 4454) in reviewing this work described

Lam Lay Yong's translation as more than a "*captatio benevolentiae*; it is a profound historical survey of the somewhat complex material formed by Yang Hui's publications." He further praises her analysis for discussing broader contexts within which Yang Hui's work must be appreciated, not only within Chinese mathematics, but in comparison with mathematical traditions beyond China, e.g. "world mathematics," as well.

Hoe, in his review, emphasizes that "Yang Hui's techniques were developed primarily for increasing the student's computational skill and speed on the counting board. Operations which on the counting board are very simple and rapid often appear cumbersome and unnecessary if thought of in terms of pencil and paper calculations." He warns, therefore, that "any adequate description of counting-board procedures in English must inevitably be long-winded and tedious, hindering comprehension and obscuring the simplicity and speed of the actual process." Hoe also emphasizes the shortcuts Yang Hui devised to speed up computations, including subtractive multiplication and factoring multipliers. He concludes his review by praising Lam's book for providing "real and substantial information about achievements in mathematics in Sung (Song) China."

Among the subjects treated in Yang Hui's writings, and which Lam discusses at length, are basic arithmetic operations, problems related to areas, solutions of quadratic equations, magic squares and circles, indeterminate analysis, and many practical applications, including musical and calendrical calculations. (Hoe points out that Lam refutes Cammann's contention that Yang Hui never described how to construct magic squares of order 4). Yang Hui's works are especially valuable because on most of these subjects his works are either the only or at least the earliest sources indicating that such subjects were studied in ancient or medieval China. And whereas earlier texts provide examples for solutions of quadratic equations, for example, Yang Hui is the first to actually explain how the calculations were to be carried out. The author notes that Yang Hui may have been influenced by Euclid on the supposition (made by others as well) that there was a Chinese translation of the *Elements* made as a result of Arabic contacts with China, but this has yet to be substantiated.

4450. Lam Lay Yong. "Chu shih-chieh's *Suan Hsüeh Ch'i-meng* [†Introduction to Mathematical Studies†]". *Archive for History of Exact Sciences* 21 (1979), 1-31.

Gives a general introduction to Zhu Shijie's *Suanxue qimeng* of 1299. Discusses the numeration, metrology and terminology found in this book, as well as the influence of the *Jiu Zhang Suan Shu* on Zhu Shijie's book.

4451. Lam Lay Yong. "Chinese Polynomial Equations in the Thirteenth Century". In *Explorations in The History of Science and Technology in*

China. Edited by Li Guohao, et al. Shanghai: Chinese Classics Publishing House, 1982, 231-272.

4452. Lam Lay Yong and Ang Tian-Se. "Li Ye and his *Yi Gu Yan Duan (= Yigu yanduan)* [†Old Mathematics in Expanded Sections†]". *Archive for History of Exact Sciences* 29 (1984), 237-266.

Beginning with a general introduction of Li Ye (also known as Li Zhi) and the background of the *Yigu yanduan*, written by Li Ye in 1259 (printed in 1282) being inspired by the mathematical book *Yigu ji* written by a certain Jiang Zhou between the last quarter of the eleventh century and the first quarter of the thirteenth century, the article goes on to discuss the general format of the book. This is done by translating problem eight and analyzing its structure. Special attention is given to how Li Ye uses the *Tian Yuan* and *Tiao Duan* methods to solve the sixty-four problems he considers, and to a comparison of the two methods. The article also presents a general analysis of the book by giving a chart which summarizes the problems and the topics they concern, along with further remarks. In their conclusion, the authors give their assessment of the value of the book: "The *Yi gu yan duan* (*Yigu yanduan*) deserves a place in history on its own for its clear and unique exposition of an intricate subject, the *tiao duan* method," (p. 264).

4453. Libbrecht, Ulrich. *Chinese Mathematics in the Thirteenth Century. The Shu-shu Chiu-chang of Ch'in Chiu-shao*. Cambridge, MA: MIT Press, 1973.

Ch'in Chiu-shao (Qin Jiushao) wrote a mathematical masterpiece in the Song dynasty, the *Shushu jiuzhang* (†Mathematical Treatise in Nine Sections†, 1257 A.D.), which Libbrecht translates with notes and commentary. One of the most important advances made in this work is the generalization it provides for the method of extracting roots, applicable for coefficients of a quadratic equation with positive or negative, integral or decimal coefficients. Most of the problems in Qin Jiushao's original text also include diagrams of the counting rod configurations which were used to explain each step in the method of extracting roots by iterated multiplication. (Li and Du, item 4222, p. 131, note that Libbrecht reproduces these diagrams, pp. 181-189, but that in his Diagram 29, for "c" read "e").

4454. Libbrecht, Ulrich. "New Studies on Chinese Mathematics. A Review Essay". *Chinese Science* 4 (1980), 65-68.

This brief note reviews recent studies of the period from the Southern Song to the Yuan dynasties, including Lam Lay Yong's *A Critical Study of the Yang Hui Suan Fa* (item 4449), and Jock Hoe's doctoral thesis at the University of Paris (items 4442 and 4444) and other works of Hoe's related to his studies of Zhu Shijie's *Siyuan Yujian* of 1303. Libbrecht notes that with studies of Qin Jiushao (see Libbrecht, item 4453), Yang Hui (item 4449), and Zhu Shijie (items 4442, 4443, 4444), the only great mathematician of this period yet to be studied in similar detail is Li Ye.

4455. Volkov, Alekseĭ [=Alexeï] Karlovich. "Science and Daoism: An Introduction". In *A Special Issue on Science in 14th Century China: A Case Study of Daoist Master and Polymath Zhao Youqin (1271-1335?).* Edited by A. Volkov. *Taiwanese Journal for Philosophy and History of Science* 5 (1996), 1-58.

This paper is an introduction to a special issue of the *Taiwanese Journal for Philosophy and History of Science* on science in 14th-century China. The introduction is devoted to a study of the interrelationships among various scientific disciplines and their cultural context in medieval China provided by the case of Zhao Youqin (1271-1335?), a scholar and a patriarch of a Daoist sect. The first part of the introduction contains a general discussion of the interrelationships between science and Daoism in China. It begins with a short outline of the viewpoints of Joseph Needham and Nathan Sivin and focuses mainly on the shortcomings of their approaches in order to identify the methodological problems one faces when dealing with this topic. This discussion demonstrates the need for a new theoretical approach to studies on the history of science in China in its cultural and social contexts, considerably distinct from those employed by Needham and Sivin. Several examples of the activities of Chinese scholars are provided to show the complexity of the interaction between various intellectual streams and religious teachings in medieval China. After this a new conceptual framework is suggested: Chinese "science" should no longer be considered as a distinct unit as far as its social and cognitive structures are concerned; instead, the author suggests that there were various centers and channels of generation, accumulation, and transmission of knowledge identified by modern scholarship as "scientific," which belonged to Confucian, Buddhist, and, notably, Daoist networks. The last part of this introduction contains a brief synopsis of Zhao Youqin's life and activity.

4456. Volkov, Alekseĭ [=Alexeï] Karlovich. "The Mathematical Work of Zhao Youqin: Remote Surveying and the Computation of π". *Taiwanese Journal for Philosophy and History of Science* 5 (1996), 129-189.

This paper is concerned with two mathematical sections of Zhao Youqin's (1271-1335?) astronomical treatise, *Ge xiang xin shu.* The first section is devoted to remote surveying (measurement of the distances of remote objects) with gnomons; here Zhao Youqin applied primarily the most ancient methods found in the *Huainanzi* (ca. 139 B.C.) and the *Zhou bi suan jing* (composed no later than the early 1st century A.D.), and introduces a modification of one of them. To justify the methods, he takes as his point of departure an idea found in the *Huainanzi* and develops it into a new approach based on the notion of the proportional relationship of two varying magnitudes; he does not use the methods of "geometrical algebra" applied by Zhao Shuang (ca. the 3rd century A.D.), and later explained in detail by Yang Hui (fl. ca. 1265). The second mathematical section of Zhao Youqin's treatise is concerned with an iterative procedure for calculating one side of a $2n$-sided inscribed polygon for $n = 3, \ldots, 14$, performed by Zhao Youqin in order to confirm Zu Chongzhi's (429-500) approximate value of 355/133 for π. The author argues that the numerical values Zhao computed may have allowed him to prove the most subtle result obtained by Zu, namely, the double inequality $3.1415926 < \pi < 3.1415927$.

4457. Volkov, Alekseĭ [=Alexeï] Karlovich. "Zhao Youqin and his calculation of *pi*". *Historia Mathematica* 24 (1997), 301–331.

The paper discusses the method used by Zhao Youqin (1271-1335?) in his treatise *Ge xiang xin shu* to confirm Zu Chongzhi's (429-500) approximate value 355/113 of π. Zhao inscribed a square into a circle and performed an iterative procedure of calculation of one side of a 2^n-sided inscribed polygon for $n = 3, \ldots, 14$. Included is a biographical sketch of Zhao, who was an astronomer, mathematician, and physicist as well as a Daoist monk and alchemist. A translation of Zhao's description of his method is given in the appendix. (**MR** 98g:01015).

4458. Yushkevich, Adol'f Pavlovich. *Istoriya matematiki v srednie veka.* (†History of mathematics in the Middle Ages†.) Moscow: GIFML, 1961. Translated as *Geschichte der Mathematik im Mittelalter*, Leipzig: B. G. Teubner, 1964.

Chapter 1 (pp. 19-105) is devoted to the history of mathematics in China. The contents are as follows: general information; ancient Chinese numerical notation; common fractions; decimal fractions; mathematics in the *Nine Chapters*; linear problems, first method of "excess and deficit"; linear problems, second method of "excess and deficit," or the rule of double false position; simultaneous equations with many unknowns; negative numbers; linear indeterminate equations; extraction of square and cube roots; problems related to quadratic equations; geometry, applications of right-angle triangles; computation of areas; computation of π; computation of volumes; geometry and algebra; cubic equations; algebra of the 13th century: the *tian-yuan* method; non-linear simultaneous equations; binomial coefficients; problems related to number theory; summing up the finite sequences; interpolation; the historical role of ancient Chinese mathematics.

4459. Yushkevich, Adol'f Pavlovich. "Issledovaniya po istorii matematiki v stranah Vostoka v srednie veka. Itogi i perspektivy". (†Studies on the History of Mathematics in the Middle Ages. The Results and Prospects.†) In *Proceedings of the International Congress of Mathematicians*. Moscow: Mir, 1968, 664-680; reprinted in

Fiziko-matematicheskie nauki v stranakh Vostoka. (†Physical and mathematical sciences in the East†.) Edited by A. T. Grigor'yan. and A. P. Yushkevich. 5, new series # 2; Moscow: Nauka, 1969, 5-17.

The author suggests a program for future research on the history of medieval mathematics in the East (pp. 7-8); the "Chinese" part of this program consists of the translation of the commentaries of Liu Hui (fl. ca. 263) on the *Jiu Zhang Suan Shu*, of the mathematical sections of the *Meng xi bi tan* by Shen Kuo, and of the algebraic treatises of Qin Jiushao, Li Ye, Yang Hui, and Zhu Shijie. Yushkevich claims that Chinese mathematics was not a collection of dispersed prescriptions empirically obtained and used to solve [isolated] problems, but rather constituted a genuine scientific discipline. He suggests that "discursive mathematical thought played an active creative role" and that "the validity of many [mathematical] methods manifested itself in the very course of the construction of the [appropriate] algorithms," and therefore the algorithms "contained their own verification, i.e., the proof of their correctness, in themselves," (p. 12). Reviewed in **MR** 40 #4057.

4460. Yushkevich, Adol'f Pavlovich. "Nouvelles recherches sur l'histoire des mathématiques chinoises". *Revue d'histoire des sciences* 35 (1982), 97-110.

The author presents an analysis of two important, recent publications on the history of Chinese mathematics that represent general surveys of research on the subject between 1955 and 1980. An English translation of Yang Hui by Lam Lay Yong and a general history of ancient Chinese mathematics by È. I. Berezkina (item 4229) are discussed. An historiographic overview of the historical literature of the past 20 years is also presented, constituting a selected and annotated bibliography of recent publications.

4461. Zharov, Valentin K. "O dvukh zadachakh traktata Devyat' knig po matematike Tsin' Tsyushao". (†On two problems in the treatise *Nine books on mathematics* by Qin Jiushao†). *Istoriko-matematicheskie issledovaniya* (*Studies in the history of mathematics*) 30 (1986), 338-343. Reviewed in **MR** 89a:01015.

European Mathematics in the Ming (1368-1644) and Early Qing Dynasties

4462. Chemla, Karine. "Que signifie l'expression 'mathématiques européennes' vue de Chine?" In *L'Europe mathématique. Histoires, Mythes, Identités.* (†Mathematical Europe. History, Myth, Identity†.) Edited by C. Goldstein, J. Gray, J. Ritter. Paris: Editions de la Maison des Sciences de l'Homme, 1996, 220-245.

It is a widely held opinion that the introduction of European mathematics by Jesuit missionaries to China in the 17th century occurred at a time when indigenous Chinese mathematics had completely disappeared. This paper first recalls the conditions under which European mathematics was introduced and, in particular, the strategic role played by science generally in the conversion efforts of Western missionaries. It then goes on to show how the *Tongwen suanzhi* was in fact an adaptation, in which indigenous knowledge, for example methods of resolution of systems of linear algebraic equations unknown to Western mathematicians of the time, were added to the original text. The Jesuits themselves never seem to have taken any interest in Chinese methods, neither those which were new nor those which were similar to the supposedly unique European creations. Later the link between mathematics and religion exploited by the Jesuits was challenged by a new generation of Chinese mathematicians who set out to recover traditional Chinese mathematics. Needham's thesis that the seventeenth century saw the creation of an international mathematics, the synthesis of Western and Chinese mathematics, may be locally true, but it was in fact the work of mathematicians of China, not of Europe.

4463. Chen Weiping. "On the 'arriving at principles from numbers' method of thought in the late-Ming, early-Qing period: A look at the nature of late-Ming, early-Qing thought from one angle". *Chinese Studies in Philosophy* 22 (1990-91), 2-23.

This article discusses the genesis, formation, and death in its infancy of the method of thinking: "*you shu da li*" (arriving at principles from numbers or by mathematics), initially raised by Xu Guangqi. Through the investigation of this Western-influenced thought in the 17th century, the author argues that Chinese philosophical thought of this period "proposed certain modernistic premises, but did not in itself possess any clear significance in renewing the form or shape of the traditional culture. [Hence it] did not directly lead to the raising of curtain on modern thought," (pp. 5-6).

4464. Hashimoto, Keizô, and Catherine Jami. "Kepler's Laws in China: A Missing Link? Jean-François Foucquet's *Lifa Wenda*". *Historia Scientiarum* 6 (3) (1997), 171-185.

In 1985 Jami found a number of Chinese manuscripts dealing with mathematics and astronomy in the Vatican Library. The mathematical manuscripts are analyzed by Jami in item 4465. The astronomical texts, which represent parts of a larger treatise, the *Lifa Wenda* (†Dialogue on Astronomy†), correspond with an almost complete version of this work in the British Library. Both are discussed in this paper, which begins by noting that whereas Matteo Ricci introduced the Ptolemaic cosmology to China, it was Tycho Brahe's system that was thereafter used by imperial astronomers and the Jesuit missionaries working at the Astronomical Bureau. An imperially commissioned work of 1742, the *Lixiang kaochang houbian* (†Sequel to the Compendium of Observational and Computational Astronomy†), introduced elliptical orbits for solar and lunar motions, for which Kepler's first two laws were used explicitly. Until now, the process of their introduction has been unclear. This paper discusses the manuscripts Jami found in the Vatican Library and the British Library, namely the *Lifa Wenda*, describes the circumstances under which it was written, and then analyzes its astronomical content with special attention devoted to the theories it used, including Kepler's laws.

Based on an historical account of progress in astronomy in Europe in the 17th century, Foucquet proposed changing some of the astronomical hypotheses and constants used by the Imperial Astronomical Bureau. Observation and construction of accurate tables, rather than cosmology, were his primary concerns, which coincide with the primary concerns of imperial astronomy to establish the calendar and predict irregular phenomena. The most remarkable innovation he proposed was the introduction of Kepler's first two laws and their application to the study of planetary motions. In 1742 the imperial astronomy adopted elliptic orbits, but retained a geocentric model. But the elliptic orbits were only applied to solar and lunar motions, and to eclipses. Planetary motions were not discussed.

4465. Jami, Catherine. "Jean-François Foucquet et la modernisation de la science en Chine. La 'Nouvelle Méthode d'Algèbre'". (Aerrebala Xin Fa), Mémoire de maîtrise, Université de Paris VII, 1986.

In 1985 Jami found a number of Chinese manuscripts dealing with mathematics and astronomy in the Vatican Library. The mathematical manuscripts are analyzed here; the astronomical texts, which represent parts of a larger treatise, the *Lifa Wenda*, correspond with an almost complete version of this work in the British Library, both of which are discussed in the author's joint paper with Keizô Hashimoto, item 4464.

4466. Jami, Catherine. "Western Influence and Chinese Tradition in an Eighteenth-Century Chinese Mathematical Work". *Historia Mathematica* 15 (1988), 311-331.

Ming Antu's (?-1765?) *Geyuan milü jiefa* (†Quick methods for trigonometry and for determining the precise ratio of the circle†) illustrates the nature of Chinese mathematics of the time, both through its history and by its contents. It contains the statement and proof of formulae for power series expansions of trigonometric functions, some of which had been introduced to China without any proof by a French Jesuit, Pierre Jartoux, at the beginning of the 18th century. The author's method consists of algebraicizing the traditional method of the "cut of the circle" (*ge yuan*). For this purpose, Ming Antu perfected an algebraic language constructed mostly by analogy with arithmetical operations. In one passage of the book, which appears as a defense of the Chinese tradition, he used another type of analogy between arithmetic and algebra based on the geometric illustration of an algorithm. The way in which Western knowledge was introduced into China determined how it was assimilated by the Chinese: Euclidean geometry was adopted in its entirety, whereas power series, divorced from their context (calculus), were reinterpreted so as to make sense within the Chinese system. At that time Chinese mathematics still maintained its independence as a kind of synthesis of two mathematical traditions.

4467. Jami, Catherine. "Classification en mathématiques: la structure de l'encyclopédie *Yu zhi shu li jing yun*". *Revue d'Histoire des Sciences* 42 (4) (1989), 391-406.

The mathematical encyclopedia *Yuzhi shuli jingyun* (†Collection of fundamental mathematical principles compiled by order of the Emperor†, 1723), which was based on European sciences introduced by the Jesuits as well as on Chinese tradition, is a synthesis of mathematics at the beginning of the Qing dynasty. Analyzing the form of mathematical discourse that appears in this work, how it takes the two traditions into account, and the organization of the mathematical information that the encyclopedia contains, leads to a better understanding of some of the elements that underlie its structure. To a certain extent, this structure reflects the conception and practice of mathematics in China at the time.

4468. Jami, Catherine. *Les Méthodes Rapides pour la Trigonométrie et le Rapport Précis du Cercle (1774). Tradition chinoise et apport occidental en mathématiques.* (Mémoires de l'Institut des Hautes Études Chinoises, 32.) Paris: Collège de France, 1990.

This work, based on the author's Ph.D. thesis (defended in 1985), is devoted to a Chinese mathematical treatise of the 18th century, in which Ming Antu deals with the development of trigonometric functions into power series. Jami starts by placing it into the context of the history of science in China after contact with the West. The starting point of Ming Antu's own research was the introduction by a French Jesuit, P. Jartoux, at the beginning of the 18th century, of some developments of trigonometric functions into power series. Jartoux's formulas, presented without any mathematical context or proof, reflect the unsystematic transmission of knowledge that could occur by means of the missionaries. Ming Antu elaborated on these formulas at a time when Jesuits had been almost completely expelled from China, hence at a time when there was most probably little or no scientific connection between China and the West. Thus he represents those Chinese scholars who launched independent research activity on their own in the 18th century. This activity is characterized by the fact that Ming Antu brought into play, as Jami describes in detail, many aspects of traditional Chinese mathematics in order to provide these formulas with an appropriate context and to account for them. The synthesis of mathematical knowledge that he performed involved such elements as Euclidean geometry and root extraction using Chinese methods (to which Mei Wending devoted an essay several decades earlier). Such a synthesis did not merely aim at bringing order into mathematics, but combined elements of various origins in such a way that it produced new knowledge. The practice of independent research, typical of mathematics as it developed until the second introduction of "Western" mathematics in the 19th century, after the opium wars, provided China with communities that were prepared to engage in this second process of reception. If the case of Ming Antu holds any general lessons in this respect, the topic with which he was dealing also makes it specific in two ways. First, calculus was one of the fields that had not been transmitted at all by the Jesuits, for which the Chinese had to wait until the second half of the 19th century to discover the results obtained in the West. Second, when Ming Antu was working, only bits like the formulas introduced decades earlier by Jartoux hinted at what had become a very active field in Europe. The context that he provided them consequently calls for a comparison with the context from which they came. By confronting Ming Antu's and Newton's achievements, Jami comes to the conclusion that they are independent from one another.

4469. Jami, Catherine. "Scholars and Mathematical Knowledge in the Late Ming and Early Qing". *Historia Scientiarum* 42 (1991), 99-109.

This paper discusses two questions: what were the general conditions for the circulation of mathematical knowledge in 17th century China? What was the status of the practitioners of this knowledge? Discussion is restricted to the scholarly milieu, and does not deal with popular knowledge. Jami first emphasizes several facts: that interest in mathematics has to be understood as a manifestation of the prominence of "concrete studies" (*shixue*) at the time; and that, because of the political crisis caused by the seizure of power by the Manchus, many scholars did not hold office in imperial institutions, but mainly worked within the network of the academies. Although mathematics was in favor because of its social usefulness and the part it could play in restoring the meaning of ancient texts, it was minor officials, on behalf of the state, who mainly used mathematics for public management. Independent scholars studied mathematics as part of a general Confucian education. Jami then describes the transmission of mathematical knowledge in two imperial institutions: the Board of Astronomy and the Academy of Mathematics, created by the Emperor Kangxi. She then turns to the transmission of mathematical knowledge through networks of independent scholars. Lastly, she describes how the two milieus were in contact with each other. The second part of this study analyses the status of specialists in mathematics, and focuses on the *Chouren zhuan* (†Biographies of mathematicians and astronomers†) initiated by Ruan Yuan. The careers of four officials who practiced mathematics within imperial institutions are described to illustrate the role of mathematics in the civil service. Lastly, Jami examines the group of mathematicians chosen to be included into the *Chouren zhuan* as revealing perceptions of what it meant to contribute to mathematics at the time. The importance of family connections is stressed in both cases.

4470. Jami, Catherine. "The *Yu zhi shu li jing yun* (1723) and Mathematics During the Kangxi Reign (1662-1722)". In *Jindai Zhongguo kejishi lunwenji.* (†Science and Technology in Modern China†.) Edited by Yang Cuihua and Huang Yilong. Taipei: Institute of Modern History, Academia Sinica and Institute of History, National Tsing-hua University, 1991, 155-172.

Compiled between 1713 and 1723, the mathematical encyclopedia *Yuzhi shulijingyun* (†Imperially Commissioned Compendium of Basic Mathematical Principles†) is a product of officially sponsored scholarship meant to gather Western as well as Chinese mathematical knowledge of the time. This paper analyses the reasons behind the Emperor Kangxi's decision to undertake this compilation in the "Academy of Mathematics" which he had created. It describes the intellectual and political context within which the encyclopedia was produced, and why only Chinese scholars, and no Jesuits, contributed to its compilation. The author considers both structure and content, showing how the encyclopedia was a genuine synthesis of the two main sources of mathematics that it included. This in turn sheds new light on the reasons why some parts of mathematical knowledge available in China at the time were not included.

4471. Jami, Catherine. "Rencontre entre arithmétiques chinoise et occidentale au XVIIe siècle". In *Histoire de fractions, fractions d'histoire.* Edited by P. Benoit, K. Chemla, and J. Ritter. Basel: Birkhäuser, 1992, 351-373.

The way in which Western arithmetic was introduced to China at the beginning of the 17th century by the Jesuits was part of a vast enterprise meant to convert Chinese scholars, in which science played a key role. In contrast to Euclidean geometry, which had no counterpart in Chinese mathematics, Western arithmetic had to confront an already constituted Chinese arithmetic. In the synthesis created from the two traditions, the major changes were confined primarily to terminology, since the methods of calculation in both cases are in fact similar. The most important difference between them is the fact that whereas the Chinese used the abacus to carry out their calculations, the Europeans did theirs on paper. Differences in the diffusion of these two methods depended on social milieu: the adoption of Western mathematics resulted in a gap between popular arithmetic practiced on the abacus, and written arithmetic used by scholars. The author points out that both used different multiplication tables.

4472. Jami, Catherine. "L'histoire des mathématiques vue par les lettrés chinois (XVIIe et XVIIIe siècles): tradition chinoise et apport occidental". In *L'Europe en Chine. Interactions scientifiques,* *religieuses et culturelles aux XVIIe et XVIIIe siècles*. Edited by C. Jami and H. Delahaye (Mémoires de l'Institut des Hautes Études Chinoises, 34.) Paris: Collège de France, 1993, 147-167.

This paper aims at explaining how Chinese scholars of the 17th and 18th centuries conceived of science, both Western and Chinese, and how they viewed their history shortly after having discovered scientific knowledge from the West. In order to do so, Jami relies on writings about mathematics, and mainly on the *Chouren zhuan* (†Biographies of mathematicians and astronomers†). Jami shows that the prefaces to the first translations or adaptations of Western books from the Latin into Chinese already attempt to relate them to Chinese intellectual history. Moreover, 17th-century Chinese scientists started to investigate their own mathematical tradition. Jami shows how this was done by Mei Wending, who recovered ancient Chinese computing devices. However, Chinese scholars had a very unclear and schematic knowledge of Western science. The conception of a "Chinese origin of Western knowledge" served them as a bridge between the two histories.

4473. Jami, Catherine. "Learning the Mathematical Sciences in the Late Ming and Early Ch'ing". In *Education and Society in Late Imperial China*. Edited by B. Elman and A. Woodside. Berkeley: University of California Press, 1994, 223-256.

This paper is devoted to analyzing how mathematics and astronomy were studied in the late Ming and early Qing dynasties. It begins with an account of the various reasons why, in contrast to previous periods, scholars and imperial institutions in 17th-century China devoted particular attention to both fields, and the historical background that prompted a renewal of scientific knowledge. An encyclopedia in mathematics, astronomy, and harmonics, the *Lüli yuanyuan* (†Origins of Mathematical Harmonics and Astronomy†, 1723), the compilation of which had been ordered by the Emperor Kangxi, gives a concrete picture of what was to become the actual curriculum followed in the study of mathematics. The author provides details of the encyclopedia's mathematical content and organization. The various contexts within which transmission of mathematical knowledge took place are also considered, including imperial institutions and private scholarly groups. In both cases, family transmission played an important part. After having described these separately, the author then shows the connection between the imperial institutions and private scholarly groups.

4474. Jami, Catherine. "L'empereur Kangxi (1662-1722) et la diffusion des sciences occidentales en Chine". In *Nombres, astres, plantes et viscères. Sept essais sur l'histoire des sciences en Asie orientale.*

Edited by I. Ang, and P. E. Will. (Mémoires de l'Institut des Hautes Études Chinoises, 35.) Paris: Collège de France, 1994, 193-209.

This paper depicts the role of the emperor Kangxi in the spread of "Western science" in China, as seen from Chinese and Jesuit sources, not from European sources of the time. The author first describes the intellectual and political contexts within which Western knowledge was introduced to China in the 17th and 18th centuries, and stresses the two main milieu within which scientific activities were taking place at the time: the Board of Astronomy and the scholars whose networks were based on the academies. She describes how Kangxi's interest in Western science arose during the controversy between the Jesuits and Chinese astronomers in 1668, a conflict that Kangxi settled in favor of the Jesuits. For this reason Kangxi subsequently decided to study Western science, and the paper provides some documentary evidence of how the Jesuits taught him. More generally, Kangxi aimed at developing scientific institutions in China. This paper brings to light his role in the creation of the "Academy of Mathematics" and in commissioning the compilation of the scientific encyclopedia *Lüli yuanyuan*.

4475. Jami, Catherine. "The French Mission and Verbiest's Scientific Legacy". In *Ferdinand Verbiest. Jesuit Missionary, Scientist, Engineer and Diplomat.* Edited by John Witek S. J., Nettetal: Steyler Verlag, 1995, 531-542.

In 1668, the Emperor Kangxi, finding the calendar unsatisfactory, sought the opinion of the Jesuit scholar Ferdinand Verbiest. The next year, Verbiest was named President of the Board of Astronomy, which had been entrusted to the Jesuits, and Verbiest also became Kangxi's teacher. The episode, which Kangxi used to political ends, inspired the Emperor to a genuine interest in Western science. This was the background for Verbiest's request that more Jesuits well versed in the sciences be sent to China, a pretext that King Louis XIV used to present Kangxi with a gift of the "King's mathematicians." The paper describes the political and scientific aims of this mission and recounts its arrival in China, in a context much dominated by Jesuits who had taken an oath of allegiance to the King of Portugal. Some of the French Jesuits were subsequently enlisted as tutors for the Emperor, inheriting one of Verbiest's positions, and documents showing how they taught the Emperor are given. Others took over Verbiest's other main position and became responsible for making the calendar. The paper describes the various attitudes toward updating astronomical knowledge from the West as taught to the Chinese, a point on which different Jesuits disagreed. It concludes with an account of how the situation at the Kangxi Court changed after Verbiest's death.

4476. Jami, Catherine. "From Louis XIV's court to Kangxi's court: An institutional analysis of the French Jesuit mission to China

(1662-1722)". In *East Asian Science: Tradition and Beyond*. Edited by K. Hashimoto, et al. Osaka: Kansai University Press, 1995, 493-499.

This paper analyses the mission that Louis XIV sent in 1685 comprised of the "King's mathematicians" to Kangxi, his counterpart in China. Being all Jesuits, the King's mathematicians not only had an evangelical mission, but were charged with political and scientific missions, the former on behalf of Louis XIV, the latter on behalf of the Académie des sciences. The first part of the paper depicts the image of China in France at the time. The author then describes the various backgrounds against which the formation of the mission to China may be understood, namely: political and scientific backgrounds in Europe, political and evangelical backgrounds in China. The various contexts are used to explain the tensions that arose among the various Jesuits in China and how this influenced the transmission of scientific knowledge from the West to China. The last part of the paper compares scientific institutions and their relation to power both in China and in France, along with an evaluation of the institutional positions of scientists within the two systems.

4477. Jami, Catherine. "Western Devices for Measuring Time and Space: Clocks and Euclidean Geometry in Late Ming and Ch'ing China". In *Time and Space in Chinese Culture*. Edited by Chun-Chieh Huang and Erik Zürcher. Leiden: Brill, 1995, 169-200.

This paper focuses on the import and reception of tools for measuring time and space brought to China by Western Jesuit missionaries, namely clocks and Euclidean geometry. It briefly reviews the role of time-keeping in China and in Europe. The role played by these tools in Jesuit evangelization strategy is also discussed. The process of reception of both elements in China is analyzed from the beginning of the 17th century until the end of the 18th century, and according to various milieus.

4478. Li Di. "The Literary Problems in the Mathematical Works of Ming Dynasty in China". *Journal of the Cultural History of Mathematics* 1 (1991), 19-27.

4479. Li Di, Bai Shang-Shu, and Michael R. Williams. "Chinese Calculators Made During the Kangxi Reign in the Qing Dynasty". *Annals of the History of Computing* 14 (4) (1992), 63-67.

This article discusses ten calculators found by the first two authors in 1978 in a store room of the Palace Museum in Beijing. These calculators are of two distinct types: "six disk/gear calculating mechanisms, similar in many ways to the more familiar Schickard or Pascal calculators, and four rod-based systems of devices that are similar to Napier's bones," (pp. 63-64). The article gives general descriptions of these instruments, and points out that they were most probably made with the help of Jesuit missionaries residing in Beijing between 1687 and 1722, when missionaries were active in the Chinese court.

4480. Martzloff, Jean-Claude. “Espace et temps dans les textes chinois d’astronomie et de technique mathématique astronomique aux XVIIe et XVIIIe siècles”. In *L’Europe en Chine. Interactions scientifiques, religieuses et culturelles aux XVIIe et XVIIIe siècles*. Edited by C. Jami and H. Delahaye. (Mémoires de l’Institut des Hautes Études Chinoises, 34.) Paris: Collège de France, 1993, 217-230. English translation in *Chinese Science* 11 (1994), 66-92.

4481. Peng, Rita Hsiao-fu. “The K’ang-hsi Emperor’s Absorption in Western Mathematics and its Extensive Applications of Scientific Knowledge”. *Lishi Xuebao* 3 (1975), 1-74.

On Euclid in China

4482. D’elia, Pasquale M. “Prezentazione della Prima Traduzione Cinese di Euclide”. *Monumenta Serica* 15 (1956), 161-202.

D’Elia notes that according to Chinese authors, the translation of volume 1 of the Clavius edition (1589) of the first six books of Euclid’s *Elements* into Chinese by Matteo Ricci and Paul Xu Guangqi in 1606-1607 “played an outstanding role during the next centuries not only in mathematical studies, but also in the formation of a scientific spirit among Chinese scholars,” (p. 200). D’Elia notes Needham’s mention of a 13th-century Chinese translation of Euclid under Mongol rule, and adds that there is evidence of a copy of Euclid in the Imperial library since 1273, heading a list of Arabic works. D’Elia’s article offers an annotated translation into Italian of the original prefaces written by Ricci and Xu for their translation of the *Elements*, and some reflections on a biographical note (also translated) in a revised edition published in Beijing in 1611. D’Elia notes that English translations of these items were made by G. E. Moule which appeared in the *Journal of the North-China Branch of the Royal Asiatic Society* 7 (1872), 147-164. D’Elia also discusses the enthusiasm Xu expressed for Euclidean geometry, praising its lucidity, certainty, logical coherence, and moral virtues. Among his observations, Xu reversed a well-known Chinese saying to emphasize the value of Euclid: “I show you an embroidery of a pair of Mandarin ducks, but I do not give the embroidery needle to anybody.” Xu appreciated the fact that geometry did not keep its methods secret, but made clear the means whereby the finished embroidery could be produced by anyone with patience enough to study the Euclidean *Elements*.

4483. Engelfriet, Peter. “The Chinese Euclid and its European Context”. In *L’Europe en Chine. Interactions scientifiques, religieuses et culturelles aux XVIIe et XVIIIe siècles*. Edited by C. Jami, and H. Delahaye

(Mémoires de l'Institut des Hautes Études Chinoises, 34.) Paris: Collège de France, 1993, 111-135.

Presents the European context and emphasizes the existence of different views and versions of Euclid's *Elements* before its introduction into China in 1607. This article seeks to explain why Matteo Ricci and Xu Guang-Qi only translated the first six books of the *Elements*, and why the Chinese version failed to convey the core of the original *Elements*, i.e. the concepts of rigorous proof and deductive method.

4484. Martzloff, Jean-Claude. "La Compréhension Chinoise des Méthodes Démonstratives Euclidiennes au Cours du XVIIe Siècle et au Début du XVIIIe". In *Actes du IIe Colloque International de Sinologie: Les Rapports entre la Chine et l'Europe au Temps des Lumières, Chantilly, 16-18 Sept. 1977.* Paris: Les Belles Lettres, 1980, 125-143.

The aim of the paper is to understand why the Chinese translation of the first six books of the Clavius version of Euclid's *Elements* was not well understood in 17th-century China. It stresses that some of the Chinese mathematicians who were interested in Euclidean geometry at that time did not pay much attention to the logical axiomatic-deductive structure of Euclid's *Elements*. This is how the author accounts for the new translations of geometrical textbooks which appeared in China in the 18th century and which were completely different from the first translation in terms of logical rigor and the arrangement of theorems.

The paper also seeks to analyze the changes brought about in the practice of mathematics in China due to the introduction of such a book as Euclid's *Elements*. Thus Martzloff devotes some attention to the adaptation by Chinese authors of geometrical European books. In the paper, Martzloff describes various Chinese books of the 17th and 18th centuries that were partly translations, partly adaptations, of European books on geometry. In a second part, works by Chinese authors on the subject are listed, and some of their statements are translated to indicate the extent to which they were receptive to Western mathematical ideas. An appendix is devoted to Mei Wending's proof of the so-called "Pythagorean theorem."

4485. Martzloff, Jean-Claude. "La Géometrie Euclidienne selon Mei Wending". *Historia Scientiarum* 21 (1981), 27-42.

This paper explains how the 17th-century scholar Mei Wending interpreted Euclid's *Elements* on the basis of the ancient Chinese geometry of the right-angled triangle. The thesis that Mei wanted to prove was that all of Euclid's geometry was in fact contained in ancient Chinese geometry, because the so-called Pythagorean theorem seemed to play a key part in it. Martzloff describes how Mei dealt with the principles of right-angled triangles in the Chinese way, and reconsiders problems taken from Chinese sources. He then shows how Mei understood the meaning and aim of Euclid's *Elements*. Lastly, Martzloff analyses how Mei confronts both geometries, and he tries to qualify Mei's conception of proof in geometry. It is noteworthy how Mei set out to prove a theorem about polyhedra which had been introduced without proof, and how, when he succeeded in proving it, he concluded that Western geometry was not a "secret teaching of the Gods" as he understood the Jesuits to have described it.

4486. Martzloff, Jean-Claude. "Eléments de reflexion sur les réactions chinoises á la géometrie Euclidienne á la fin du XVIIe siècle-le *Jihe lunyue* de Du Zhigeng vu principalement á partir de la préface de l'auteur et de deux notices bibliographiques rédigées par des lettrés illustres". *Historia Mathematica* 20 (1993), 160-179, and 460-463.

The *Jihe lunyue* (1700) is a compendium of the Chinese translation (1607) of the first six books of the Clavius edition of Euclid's *Elements*. Three later Chinese texts are translated and annotated in this paper in order to provide some background for the reaction to the introduction of Western geometry in 17th-century China: Du Zhigeng's preface to his *Jihe lunyue*; the bibliographical notice of the book published in the Imperial catalogue of the *Siku quanshu*; and the bibliographical notice concerning Mei Wending's *Jihe zhaiyao* (†Essentials of geometry†).

Martzloff concludes from these sources that for Du Zhigeng, far from being the *summum* of logical clarity, the "rhetoric" of the proofs of the *Elements* was abstruse and harmful, since he suspected they conveyed pernicious modes of reasoning such as those which structured the theological writings of Jesuit missionaries. Hence the idea of abridging the text of the *Elements* to strip away the axiomatic-deductive "rhetoric." This would offer young mathematicians a set of simple and efficient geometrical techniques in conformity with the ideals of the movement in China to promote "concrete studies" (*shixue*), so important in China in the 17th and 18th centuries. A glossary of Chinese characters for the article was published later in the same journal, along with some errata.

4487. Martzloff, Jean-Claude. "Note on the Recent Chinese and Mongolian Translations of Euclid's *Elements*". *Historia Mathematica* 24 (1997), 200-202.

4488. Masini, Federico. "The Legacy of Seventeenth Century Jesuit Works: Geography, Mathematics and Scientific Terminology in Nineteenth Century China". In *L'Europe en Chine. Interactions scientifiques, religieuses et culturelles aux XVIIe et XVIIIe siècles*. Edited by C. Jami, and H. Delahaye (Mémoires de l'Institut des Hautes Études Chinoises, 34.) Paris: Collège de France, 1993, 137-146.

Part of this article discusses the influence of the translation into Chinese made by Matteo Ricci and Xu Guangqi of the first six books of Euclid's *Elements* in 1607, compared with the translation made of the last nine books of the *Elements* made in 1857 by Alexander Wylie and Li Shanlan; special emphasis is given to terminology.

4489. Mo De and Jiang Zhenhua. "The Recent Chinese and Mongolian Translations of Euclid's *Elements*". *Historia Mathematica* 24 (1997), 197-199.

4490. Moule, G. E. "The Obligations of China to Europe in the Matter of Physical Science Acknowledged by Eminent Chinese; Being Extracts from the Preface to Tsang Kwo-Fan's [Zeng Guofan] Edition of Euclid with Brief Introductory Observations". *Journal of the North China Branch of the Royal Asiatic Society* 7 (1873), 147-164.

This article offers the first English translation of a preface by Zeng Guofan to the first Chinese version of the whole fifteen books of Euclid's *Elements*, published under the sponsorship of Zeng Guofan in Nanjing in 1865, along with the two prefaces written by Xu Guangqi, and Matteo Ricci, respectively, in 1607. Before the translation, the article gives some brief remarks on these prefaces, one of which notes that Zeng "understood in some measure the importance of physical science in the practical concerns of political and private life," (p. 147). Actually, Zeng had little interest in mathematics; the preface signed by Zeng was not from his own hand, but that of his eldest son Zeng Jize, who loved mathematics and eventually became a diplomat.

On Transmission of Western Mathematics to China

4491. Bennett, Adrian Arthur. *John Fryer. The Introduction of Western Science and Technology into Nineteenth Century China*. Cambridge, MA: Harvard University Press. Reviewed by Sivin, Nathan, *Isis* 61 (1970), 280-282.

This work focuses primarily on John Fryer's activities in China from 1861 to 1895. Chapter one tells the story of Fryer as a missionary in Hong Kong, Peking, and Shanghai before 1868. Chapter two explains why Fryer changed his career to become an employee of the Qing government as a translator at the newly founded *Kiangnan* (*Jiangnan*) arsenal, and how he translated Western scientific books into Chinese; the influence of these translations is also described. Chapter three, the last chapter, recounts Fryer's promotion of Western knowledge through his teaching at the Ko-Chih Shu-Yuan (The Shanghai Polytechnic Institute), and evaluates the influence of the magazine he edited, *Ko-Chih Hui-Pien*.

Perhaps the most valuable part of this study is its five appendices. Appendix II, for example, lists Fryer's Chinese translations of English books (pp. 82-102), and Appendix III lists translations of four other Western missionaries at the *Kiangnan* arsenal, namely Alexander Wylie, J. Allen Young, John MacGowan, and Carl Kreyer (pp. 103-109).

Sivin, in his review, points out that the Chinese title of this book, meaning "A Survey of the writing and translations of John Fryer," is "much more accurate" than its English title. He criticizes the monograph for failing to put Fryer's work in a broader social context, i.e. "the Self-strengthening Movement," in China. He concludes his review by saying, "whoever in the future sets out to do a definitive assessment of John Fryer and the scope and influence of his work will have to survey his collected papers afresh, for they need to be reread in the light of much wider study and with more broadly defined issues in mind," (p. 282).

4492. Dauben, Joseph W., and Zhang Dian-Zhou. "Mathematical Exchanges Between the United States and China". In *History of Modern Mathematics.* Edited by E. Knobloch and D. Rowe. Orlando: Academic Press, 1994, 263-297.

This article points out that the first Chinese translation of a calculus textbook, the first Chinese Ph.D. in mathematics, the first director of the first Mathematical Institute in China, and the first Chinese graduate program in mathematics were all associated with American mathematicians or supported by funds established for Chinese foreign-exchange students to study in the United States. The key factor, the Boxer Indemnity Scholarship Program, is explained. Individuals whose contributions are discussed at length include Li Yan, Elias Loomis, Li Shanlan, D. E. Smith, and Alexander Wylie; the importance of universities like Cornell, Harvard, Chicago, Beijing University, and Qing Hua University (Beijing) in training Chinese students is also described. The article closes with a consideration of the work of contemporary Chinese mathematicians since the founding of the People's Republic of China in 1949. The article is illustrated with the title pages of Elias Loomis's textbook on Calculus (1851) and the Chinese translation by Li Shanlan and Alexander Wylie (1859).

4493. Horng Wann-Sheng. (Hong Wansheng.) "Hua Hengfang (1833-1902) and His Notebook on Learning Mathematics—*Xue Suan Bi Tan*". *Philosophy and the History of Science. A Taiwanese Journal* 2 (2) (1993), 27-76.

Hua Hengfang's *Xue Suan Bi Tan* may be regarded as an attempt to modernize traditional mathematics in late 19th-century China. Despite the fact that he emphasized the methods of traditional Chinese algebra (like the "Tian Yuan" and "Si Yuan" methods), Hua's major concern was to motivate interest in the newly-transmitted mathematical knowledge from the West, such as algebra and calculus. He sought to do so through a critical discussion of traditional Chinese mathematical methods and what was then-known about Western mathematics. Horng offers here an extensive study of the *Xue Suan Bi Tan* in order to explain how Hua Hengfang was instrumental in the process of modernizing Chinese mathematics.

4494. Hu Ming-Jie. *Merging Chinese and Western Mathematics: the Introduction of Algebra and the Calculus in China, 1859-1903.* Unpublished dissertation, Princeton, N.J.: Princeton University, 1998.

Examines the social, political, and intellectual background of the introduction of Western sciences in general, algebra and the calculus in particular, to China in the second part of the nineteenth century. The major body of this dissertation discusses how and by what means algebra and the calculus were introduced, and the role traditional Chinese mathematics played in this introduction. Six appendices are included. The first two list the translated concepts, methods, and theorems of modern algebra (pp. 378-88); Appendix III presents important concepts of the calculus (pp. 389-91).

4495. Jami, Catherine. "Western Mathematics in China, Seventeenth Century and Nineteenth Century". In *Science and Empires.* Edited by P. Petitjean, C. Jami, and A.-M. Moulin. Dordrecht: Kluwer Academic Publishers, 1992, 79-88.

The purpose of this paper is to compare the two main periods during which transmission of mathematics from the West to China occurred: from the 16th century onwards, by the intermediary of European Jesuits, and from the second half of 19th century onwards, after the Opium War (1839-1842). These two periods are compared from different perspectives: motivations on both sides, means of transmission, institutional frameworks, the reception of Western mathematics by Chinese scholars, and how the new knowledge stood in relation to previous mathematical traditions. Jami's comparisons bring to light some similarities such as the part played in both periods by missionaries. Among differences, Jami stresses that in the 17th century the reception of Western knowledge was determined by dynamics internal to Chinese history, and that Western knowledge was interpreted as belonging to Chinese tradition. In the 19th century, however, Western mathematics was vital because it was regarded as the key to military power, and thus it was actively studied so as to enable the Chinese to turn Western weapons against the West.

4496. Jami, Catherine. "From Clavius to Pardies: the Geometry Transmitted to China by Jesuits (1607-1723)". In *Western Humanistic Culture Presented to China by Jesuit Missionaries (XVII-XVIII centuries): Proceedings of the Conference Held in Rome, October 25-27, 1993.* Edited by Federico Masini. (Bibliotheca Instituti Historica S.I., 49.) Rome: Institutum Historicum S.I., 1996, 175-199.

Three versions of Euclidean geometry were published in China between 1607 and 1723, and this paper considers criteria for evaluating their differences: the translation by Ricci and Xu Guangqi of the first six books of Euclid's *Elements* (from the edition by Clavius, *Jihe yuanben*, 1607); the *Jihe yaofa* (†Essential Methods of Geometry†) published by Aleni with the help of Qu Shigu in 1631; and the version of the *Elements* that was included in the encyclopedia composed at the request of the Emperor Kangxi, *Yuzhi shuli jingyun* (1723). The point is to counter the idea that, at the time when Euclidean geometry was introduced by Ricci to China shortly after his arrival, it was a stilted entity in Europe. On the contrary, the author shows how expectations vis-á-vis geometrical texts were changing in Europe in the course of the 17th century, in a context that is especially important when considered in terms of China and the evolution of education in Jesuit colleges. Jami stresses how the various audiences that Jesuits addressed in China during the 17th century caused them to use their geometrical knowledge in various ways in their publications, and how they made use of new ways of presenting geometrical knowledge as it became available in Europe when such innovations fitted with the demands they met with in China.

4497. Jami, Catherine. "Aleni's contribution to geometry in China. A study of the *Jihe yaofa*". In *"Scholar from the West." Giulio Aleni S.J. (1582-1649) and the Dialogue between Christianity and China*. Edited by T. Lipiello, and R. Malek. Nettetal: Steyler Verlag, 1997, 555-572.

This paper aims at shedding some light on the activities of the Jesuit missionary Giulio Aleni in China through an analysis of his *Jihe yaofa* (†Essential Methods of Geometry†), a mathematical book published in Chinese in 1631. The *Jihe yaofa* relied on Ricci and Xu Guangqi's Chinese translation (1607) of the first six books of Euclid's *Elements*, which was based on the Clavius edition. In contrast to the latter, the main emphasis of the *Jihe yaofa* was upon geometrical constructions, and the article shows how the constructions and instruments with which to perform them dictated the basic organization of the book. The *Jihe yaofa* was subsequently chosen as the book on geometry that was officially reprinted in the collection of Jesuit books on mathematics and astronomy, the *Xinfa suanshu* (†Computation Books According to a New Method†), published shortly after the founding of the Qing dynasty. Consequently, it overshadowed the influence of Ricci and Xu Guangqi's translation of the *Elements* in China. The article concludes with the hypothesis that, again in contrast to the Ricci/Xu Guangqi translation of the *Elements* which was written for high officials, the *Jihe yaofa* may have been written for another audience, either for minor officials of the Board of Astronomy or for local gentry.

4498. Jami, Catherine. "Mathematical knowledge in the *Chongzhen lishu*". In *Western Learning and Christianity in China. The Contribution and Impact of Johann Adam Schall von Bell S.J. (1592-1666).* Edited by Roman Malek. Nettetal: Steyler Verlag, 1998, 661-674.

After the first generation of missionaries to China, who set out to translate into Chinese or adapt on their own the main mathematical textbooks in use at the Collegio Romano at the time, the second generation gathered together the *Chongzhen lishu* (†Calendar of the

Chongzhen era†) within an official framework. The collection was presented to the Emperor in 1631 and became the official corpus of knowledge and methods in China for calendar-making. It was reprinted, with modifications, several times, and Jami's paper is concerned with the form it took to be included in the *Siku quanshu* at the end of the 18th century under the title *Xinfa suanshu* (†Computation Book according to the new method†). Jami analyses where, in the collection, books devoted to mathematics were placed. After describing the contents of these books, Jami stresses the focus placed on instruments in all of them. She then shows that Xu Guangqi put them all in the part of the *Chongzhen lishu* devoted to "fundamental items," specifying for most of them the category to which they belonged. She then studies the occurrences, throughout the collection, of a mathematical object which appeared for the first time in Chinese: the ellipse. Her conclusion concerns the contexts within which research on conic sections developed in China prior to the Opium war.

4499. Swetz, Frank J. "The Introduction of Mathematics in Higher Education in China, 1865-1887". *Historia Mathematica* 1 (1974), 167-179.

4500. Swetz, Frank J.. *Mathematics Education in China, its Growth and Development.* Cambridge, MA: The MIT Press, 1974.

On Mathematics in the Late Qing Dynasty

4501. Li Wenlin. "The Chinese Indigenous Tradition of Mathematics and the Conceptual Foundation to Adopt Modern Mathematics in the 19th Century". In *Zhongguo shuxueshi lunwenji* (†Collected Papers on the History of Chinese Mathematics†.) Edited by Bai Shangshu, Li Di, and Shen Kangsheng. Jinan: Shangdong Educational Press, 1996, 146-156.

This article discusses mathematical research produced by Chinese mathematicians from the beginning of the 18th century to the middle of the 19th century. The author points out that the research carried out in this period was both shaped by Chinese tradition and inspired by newly introduced European mathematics. Examples are given of infinitesimal approaches, power series, and algebra. After having presented Chinese contributions to these areas, the author concludes his paper by saying, "Although they [the Chinese] were not able on their own to construct a systematic theory such as the calculus, their work at least formed an important conceptual foundation enabling them to adopt modern mathematics successfully when it was later introduced from Europe," (p. 156).

4502. Luo Jian-Jin. "The Contributions of Chinese Mathematics to Counting Theory in the Qing Dynasty (Summary)". *Journal of the Cultural History of Mathematics* 2 (1992), 56-58.

This article outlines some general results in the field of counting theory obtained by Li Shanlan, Hua Hengfang, Xu Youren, Dai Xu, and other Chinese mathematicians in the nineteenth century.

Mathematics in Modern China

4503. Dauben, Joseph W. "Mathematics and Ideology: The Politics of Infinitesimals/ Marx, Mao and Mathematics: Nonstandard Analysis and the Cultural Revolution". *Proceedings of the III Simposio Internacional Galdeano, Zaragoza: University of Zaragoza, Spain, September, 1996*. (in press).

The "Mathematical Manuscripts" of Karl Marx were first published (in part) in Russian in 1933, along with an analysis by S. A. Yanovskaya. Friedrich Engels was the first to call attention to the existence of these manuscripts in the preface to his *Anti-Dühring* (1885). A more definitive edition of the "Manuscripts" was eventually published, under the direction of Yanovskaya, in 1968, and subsequently numerous translations have also appeared. Marx was interested in mathematics primarily because of its relation to his ideas on political economy, but he also saw the idea of variable magnitude as directly related to dialectical processes in nature. He regarded questions about the foundations of the differential calculus as a "touchstone of the application of the method of materialist dialectics to mathematics."

Nearly a century later, Chinese mathematicians explicitly linked Marxist ideology and the foundations of mathematics through a new program interpreting calculus in terms of nonstandard analysis. During the Cultural Revolution (1966-1976), mathematics was suspect for being too abstract, aloof from the concerns of the common man and the struggle to meet the basic needs of daily life in a still largely agrarian society. But during the Cultural Revolution, when Chinese mathematicians discovered the mathematical manuscripts of Karl Marx, these seemed to offer fresh grounds for justifying abstract mathematics, especially concern for foundations and critical evaluation of the calculus. At least one study group in the Department of Mathematics at Zhejiang Teachers College issued its own account of "The Brilliant Victory of Dialectics —Notes on Studying Marx's 'Mathematical Manuscripts'."

Inspired by nonstandard analysis, introduced by Abraham Robinson only a few years previously, some Chinese mathematicians adapted the model Marx had laid down a century earlier in analyzing the calculus, and especially the nature of infinitesimals in mathematics, from a Marxist perspective. But they did so with new technical tools available thanks to Robinson but unknown to Marx when he began to study the calculus in the 1860s. As a result, considerable interest in nonstandard analysis has developed subsequently in China, and almost immediately after the Cultural Revolution was officially over in 1976, the first all-China conference on nonstandard analysis was held in Xinxiang, Henan Province, in 1978.

4504. Horng Wann-Sheng (Hong Wansheng). "Chinese Mathematics at the Turn of the 19th Century: Jiao Xun, Wang Lai and Li Rui". In

Philosophy and Conceptual History of Science in Taiwan. Edited by Lin Cheng-Hung, and Fu Daiwie. (Boston Studies in the Philosophy of Science, vol. 141.) Dordrecht: Kluwer Academic Publishers, 167-208.

This work analyzes the advances made by Chinese mathematicians working in the 19th century in the tradition of the Qian-Jia school, which was devoted to investigating and extending the works of earlier Chinese mathematicians. Wang Lai, who collected and studied the works of the great Song-Yuan masters, Qin Jiushao, Li Ye and Zhu Shijie, provided a new stimulus in the mid-Qing dynasty for the study in particular of general rules for solving equations. Through the works of Jiao Xun and Li Rui as well, the investigation of quadratic and cubic equations was greatly extended. This article examines how and to what extent Jiao Xun (1763-1820), Wang Lai (1768-1813), and Li Rui (1769-1817) went well beyond the traditional algebra associated with 13th-century mathematicians. Horng Wann-Sheng focuses on how Jiao Xun, Wang Lai, and Li Rui approached mathematics largely in terms of the epistemology and methodology of the Qian-Jia school.

4505. Hua Loo-Keng. "Mathematical Research in China in the Last Ten Years". *Notices of the American Mathematical Society* 6 (1959), 724-730. Originally in *Kexue tongbao* 18 (1959), 565-567, in Chinese.

This article is devoted to progress in mathematics made in China during the period 1949-1959. Beginning with a comparison of statistics in this period and the early part of this century, the article goes on to give a general survey of achievements in various branches of modern mathematics in the decade 1949-1959, concluding that "in comparison with the period before the liberation [in 1949], our confidence has been doubled. . . . We, the Chinese mathematical workers. unanimously recognize that it is possible in China to make great progress at a rapid rate in the field of mathematics," (p. 729). Following the translation there is a short biography of the author by Lowell Schoenfeld.

4506. Stone, Marshall H. "Mathematics, 1949-1960". In *Sciences in Communist China*. Edited by Sidney H. Gould. Washington, D.C.: American Association for the Advancement of Science, (Publication No. 68) 1961, 617-630.

Here Stone offers his own appraisal of mathematical research done by Chinese mathematicians during the period 1949-1960. While acknowledging some important results in the theory of analytic functions, number theory, differential geometry, and topology, the article points out that Chinese contributions have thus far created "no very great stir in mathematical circles," (p. 619). The paper also notes the traditional emphasis Chinese mathematics has placed on applications.

In the third section, Stone gives a brief account of the development of modern mathematics in China, and also draws some comparisons with developments in Japan, the United States, and former Soviet Union. It also describes relations between China and other countries, as well as the International Mathematical Union and the Congress of Mathematicians in the 1950s. As for the future of mathematics in China, the paper predicts, wrongly at least for the 1960s and 1970s, "that we shall eventually see mathematics in continental China reach a very high level of activity, whether we view it in terms of quality or quantity," (p. 625).

4507. Tsao Chia-Kuei. *Bibliography of Mathematics Published in Communist China During the Period 1949-1960.* Providence, R.I.: American Mathematical Society, 1961.

This pamphlet lists 1271 titles published between 1949 and 1960 by 308 mathematicians in mainland China. It also includes a roster of Chinese periodicals in which these articles may be found, along with the number of titles cited from each periodical.

4508. Yuan Tung-li (Yuan Tong-li). *Bibliography of Chinese Mathematics, 1918-1961.* Washington: published privately, 1963.

A list of mathematical articles by Chinese mathematicians (and a few physicists) published in journals throughout the world between 1918 and 1960. The bibliography has a foreword by Shiing-Shen Chern, but the bibliography itself offers neither critical remarks nor annotations.

Individual Mathematicians

4509. Ang Tian-Se. *I-Hsing (Yixing) (683-727 AD): His Life and Scientific Work*, Kuala Lumpur: University of Malaya. Unpublished Ph.D. Thesis.

4510. Cheng, S. Y., et al., eds. *Shiing-Shen Chern (Chen Xingshen): A Mathematician and His Mathematical Work*. Singapore: World Scientific, 1996.

This book is divided into three parts. The first part includes six introductory articles on Chern's educational background and mathematical contributions by R. S. Palais, C.-L. Terng, A. Weil, P. A. Griffiths, and W.-L. Chow, as well as by Chern himself. The second part includes 25 selected articles in different areas of geometry published by Chern and his collaborators in the period 1932-1987. The third and last part collects Chern's 14 publications since 1988. Three appendixes at the end of the book present Chern's curriculum vitae, the list of Ph.D. dissertations written under his supervision, and a bibliography of his publications.

4511. Chinn, William, and John Lewis. "Shiing-Shen Chern [Chen Xingshen]". In *Mathematical People, Profiles and Interviews*. Edited by

Donald J. Albers and G. L. Alexanderson. Basel: Birkhäuser, 1985, 33-40.

This article is based on an interview by the authors at the temporary facilities of the Mathematical Sciences Research Institute in Berkeley on October 8, 1982, shortly after Professor Shiing-Shen Chern, a renowned geometer, was selected by the National Science Foundation as the Director of the Institute. The article relates his educational experience, major contributions to differential geometry, and academic activities, along with some basic biographical information. The authors also point out that Chern was a great educator. Among his many students are the Nobel laureate (1957) Chen-Ning Yang, Fields Medalist (1982) Shing-tung Yau, and a well-known topologist and historian of Chinese mathematics, Wu Wenjun. Three photos, two of Chern himself, one with his family, and one page of Chern's Chinese calligraphy, as well as a musical score entitled "Hail to Chern," are included.

4512. Ho Peng-Yoke. "Ch'in Chiu-shao [Qin Jiushao]." In *Dictionary of Scientific Biography.* Vol. 3. New York: Scribner's, 1971, 249-256.

Discusses the life and works of Qin Jiushao, especially his celebrated mathematical treatise, the *Shushu Jiuzhang* (†Mathematical Treatise in Nine Sections†) of 1247. Each of the nine sections of this work includes two chapters made up of nine problems. These cover indeterminate analysis; astronomical, calendrical, and meteorological calculations; land measurement; triangulation surveying methods; land taxes; money and grains; architectural constructions; military matters; barter and trade. With this work the Chinese study of indeterminate analysis reached its peak; one problem (in Chapter 8) requires solution of an equation of degree 10; another (in Chapter 9) has 180 answers.

4513. Ho Peng-Yoke. "Chu Shih-chieh. [Zhu Shijie]". In *Dictionary of Scientific Biography.* Vol. 3. New York: Scribner's, 1973, 265–271.

Except for what is known from the preface to his *Siyuan yujian* (†Precious Mirror of the Four Elements†), there is no record of Zhu Shijie's personal life. The *Siyuan yujian*, written in 1303, represents Chinese algebra at the height of its development, marking the end of a golden age for Chinese mathematics. For the first time, the "method of the celestial element" was extended to express four unknowns in the same algebraic equation, and subsequently this came to be known as the "method of the four elements." Ho Peng-Yoke explains how the method was applied using counting rods on a counting board; he then discusses a variety of specific problems, including square roots, application of the Chinese version of the Pascal triangle, infinite series, progressions, and the method of finite differences.

4514. Ho Peng-Yoke. "Li Chih [Li Zhi]". In *Dictionary of Scientific Biography.* Vol. 8. New York: Scribner's, 1973, 313-320.

Li Zhi (also known as Li Ye, 1192-1279), whose most important mathematical work was the *Ceyuan haijing* (†Sea Mirror of Circle Measurements†), completed in 1248, introduced an algebraic process—*Tian Yuan Shu* (Method of the Celestial Element)—for setting up equations of any degree. Li Zhi made use of numerical equations as high as degree 6. The *Ceyuan haijing* includes 170 problems based on various ways a circle can be inscribed in or circumscribed about a right triangle.

4515. Ho Peng-Yoke. "Liu Hui". In *Dictionary of Scientific Biography.* Vol. 8. New York: Scribner's, 1973, 418-425.

Despite the fact that nothing is known about Liu Hui, except that he lived in the Kingdom of Wei during the Three Kingdoms Period (221-265 A.D.), his commentary on the *Jiu Zhang Suan Shu* (†Nine Chapters of the Art of Mathematics†) and the *Hai Dao Suan Jing* are the focus of study here. Ho Peng-Yoke analyzes specific problems and discusses the overall significance of Liu Hui's commentary and treatise, giving a detailed appreciation of their contents and the methods Liu Hui used.

4516. Ho Peng-Yoke. "Yang Hui". In *Dictionary of Scientific Biography.* Vol 14. New York: Scribner's, 1976, 538-546.

Yang Hui (also known as Qianguang), a native of Qiantang (present-day Hangzhou), collected together problems and methods of several kinds from mathematical works that had long been lost, including the "method of extracting roots by iterated multiplication" and "the source of the method of extracting roots," which survive to the present thanks to Yang Hui. Among his many works, his *Chen chu tong bian suan bao* (†Precious Reckoner for Variations of Multiplication and Division†) was a popular and practical syllabus for teaching mathematics in his day, and sheds useful light on mathematical education generally in those times. For studies of his *Riyong suan fa* (†Computing Methods for Daily Use†, 1262 A.D.), see Lam Lay-Yong, item 4448, and for a translation and detailed commentary on the *Yang Hui suanfa* (†Yang Hui's Methods of Computation†, 1274-1275 A.D.), see Lam Lay-Yong, item 4449. Among other classic problems, Yang Hui's *Xugu zhaiqi suanfa* (†Continuation of Ancient Mathematical Methods for Elucidating the Strange [Properties of Numbers]†, 1275 A.D.), includes the famous 100 fowls problem.

4517. Horng Wann-Sheng. (Hong Wansheng). *Li Shanlan: The Impact of Western Mathematics in China During the late Nineteenth Century.* Unpublished dissertation, New York: City University of New York, 1991.

A detailed study of Li Shanlan's life and works, drawing on primary and secondary sources in Chinese and Western languages.

4518. Jami, Catherine. "History of Mathematics in Mei Wending's (1633-1721) Work". *Historia Scientiarum* 4 (1994), 159-174.

This article analyses research that, at the beginning of the Qing dynasty, Mei Wending devoted to history of mathematics, especially to reconstruction of the number system and the computing tools with which mathematicians practiced mathematics in ancient China. Jami emphasizes what was at stake in such historical research in 17th-century China, when scholars were confronted with the introduction by Jesuit missionaries of Western mathematics that was deemed superior. The paper first compares Mei Wending's studies devoted to the history of mathematics with elements of the history of astronomy he also gathered. This remarkable scholar, whose results and research methods were to have a considerable influence on the works of later mathematicians in China, combined historical studies and mathematics in a special way. Jami analyses his techniques of historical research, and assesses his results by comparing them to contemporary history of science. She also examines the connections between Mei Wending's research and the more general movement of philological studies (*kaozheng*) to which his work can be related.

4519. Kobori, Akira. "Tsu Ch'ung-chih". In *Dictionary of Scientific Biography.* Vol. 13. New York: Scribner's, 1976, 484-485.

Tsu Ch'ung-chih [Zu Chongzhi] (429–500) was a famous astronomer and mathematician during the Liu Song (420–479) and Qi (479–502) dynasties. In 462 a new calendar was constructed by him, known as the Daming Calendar, which was controversial at the time and led to a public debate (that has been characterized as a reflection of the struggle between science and anti-science in Zu Chongzhi's day), and was only adopted ten years after Zu Chongzhi's death. His most remarkable accomplishment, however, was his calculation of pi recorded in the "Lüli zhi" (†Memoir on the Calendar†) chapter of the *Sui shu* (†History of the Sui Dynasty†). In this work, Zu Chongzhi's approximation, accurate to 7 decimal places, is given along with a brief reference to his method of calculation which required the diameter of the circle be divided into 100,000,000 parts before determining the circumference of the circle.

4520. Li Yan' (Li Yan). "Tszu Chun-chzhi – vydayushchiĭsya matematik drevnego Kitaya". (†Zu Chongzhi, an outstanding mathematician of ancient China†.) *Narodnyĭ Kitaĭ* (*People's China*) 20 (1956), 30-34.

4521. Li Zhao-Hua. "Wang Lai's Research on Number Systems of Variable Base". In *Science and Technology in Chinese Civilization*. Edited by Chen Cheng-Yih, Roger Cliff, and Chen Kuei-Mei. Singapore: World Scientific Publishing Co., 1987, 87-92.

Discusses multiplication and multiplication tables in number systems with different bases, as well as the definition and calculation of "proper denominators" in the *San Liang Suan Jing* of Wang Lai (1768-1813).

4522. Li Zhao-Hua. "A Study of the Mathematical Works of Li Shan-Lan (Li Shanlan)". in *Science and Technology in Chinese Civilization.* Edited by Chen Cheng-Yih, Roger Cliff, and Chen Kuei-Mei. Singapore: World Scientific Publishing Co., 1987, 109-126.

Briefly discusses the contents of the *Fang Yuan Chan You* of 1845 and the *Duo Ji Bi Lei* of 1859, pointing out the connection between the two books (namely the relationship between the curved surface pyramid and piling problems).

4523. Lih Ko-Wei. "Bao Qi-Shou (Bao Qishou) and His Polyhedral *Hun Yuan Tu*". In *Science and Technology in Chinese Civilization.* Edited by Chen Cheng-Yih, Roger Cliff, and Chen Kuei-Mei. Singapore: World Scientific Publishing Co., 1987, 93-107.

4524. Lih Ko-Wei. "Bao Qi-shou (Bao Qishou) and His Polyhedral *Hun Yuan Tu*". In *Philosophy and Conceptual History of Science in Taiwan.* Edited by Lin Cheng-Hung and Fu Daiwie. (Boston Studies in the Philosophy of Science, vol. 141.) Dordrecht: Kluwer Academic Publishers, 1993, 209-220.

There is a long history of magic squares in China, going back to the mystical Luo Shu of ancient China. In 1275, Yang Hui published his *Xu Gu Zhai Qi Suan fa* (†Continuation of Ancient Mathematical Methods for Elucidating the Strange Properties of Numbers†), the first part of which lists twenty "zong heng tu" (vertical and horizontal diagrams). The term includes, in addition to magic squares, circular arrangements of consecutive numbers for which a constant sum along any of the prescribed directions always results. Constructions of "*zong heng tu*" were further pursued in works by later mathematicians, including Ding Yidong (Song dynasty), Cheng Dawei (1593), Fang Zhongtong (1661), and Zhang Chao (1670). But the construction of "*zong heng tu*" was raised to a higher dimension when Bao Qishou took up the problem in the late 19th century. In this article, Lih Ko-Wei analyzes many of Bao's results, including those for the groups of cubes, tetrahedra, octahedra, dodecahedra, icosahedra, and icosadodecahedra. Lih concludes that Bao's work should be ranked among the highest in combinatorial mathematics of the 19th century. Especially important is the extent to which Bao's constructions can be generalized. When interpreted in terms of graph theory, Bao's constructions are labelings of plane graphs such that the edges do not cross each other except at vertices. Both constant-sum and consecutive labelings can be defined for such general plane graphs. The author concludes with brief mention of his own constructions for several infinite families of graphs.

4525. Luo Jian-Jin. "A Brief Biography of Lu Jiaxi". *Journal of the Cultural History of Mathematics* 2 (1992), 59-60.

Lu Jiaxi (June 10, 1935-Oct. 31, 1983) was a high school teacher at Baotou City, Inner Mongolia, China. Under very difficult conditions, he devoted himself to the study of the Kirkman schoolgirl problem, and to large sets of disjoint Steiner triple systems, among others in the field of balanced incomplete block design. This article gives a very brief account of his life and his mathematical achievements.

4526. Martzloff, Jean-Claude. *Recherches sur l'Oeuvre Mathématique de Mei Wending (1633-1721).*(*Mémoires de l'Institut des Hautes Études Chinoises*, 16.) Paris: Collège de France, Institut de Hautes Études Chinoises, 1981. Stanislas Julien Prize 1982.

This book is devoted to the greatest Chinese mathematician and astronomer of 17th-century China, Mei Wending. After depicting the situation of scholarship and more particularly that of mathematics in China during the 17th century, Martzloff describes the various books ascribed to Mei Wending and examines the different editions available. He then turns to analyzing various aspects of Mei Wending's mathematical works. This 17th-century Chinese scholar devoted some attention to reconstituting the ancient Chinese methods of performing computations with counting rods on a board, and investigated several ancient arithmetical algorithms. He also described the use of several Western tools for computations brought to China by the Jesuits (including Napier's rods and Galileo's geometric and military compass). Moreover, Mei Wending reconstituted several ancient Chinese algorithms to compute the nth root of a number or to determine the root of an algebraic equation. This work was based on Chinese sources written prior to the transmission of mathematics from the West by the Jesuits. This led Mei Wending to compare Chinese methods for handling the same problems with Western sources. He concluded that Chinese sources contained algorithms similar to those available in Western sources, and developed independently from the latter. Mei Wending also restored the ancient Chinese algorithm for solving systems of linear equations (*fangcheng*). To do so he had to correct many mistakes that had affected the method in the course of transmission from the beginning of the common era until the 16th century. He compared this to the method of double false position used by Clavius. In this case, Mei concluded that the ancient Chinese method was superior. The last part of Martzloff's book is devoted to the synthesis that Mei Wending forged between Euclidean geometry and ancient Chinese geometry as he understood it. This in turn led him to an algebraic reading of book 2 of the *Elements*.

4527. Martzloff, Jean-Claude. "Matteo Ricci's Mathematical Works and their Influence". In *International Symposium on Chinese-Western Cultural Interchange in Commemoration of the 400th Anniversary of the*

Arrival of Matteo Ricci S.J. in China. Taipei, 11-16 Sept., 1983. Taipei: Furen Daxue Chubanshe, 1983, 889-895.

4528. Martzloff, Jean-Claude. "Li Shanlan, mathématicien chinois traditionnel". *Pour la Science* 127 (Mai, 1988), 48-57.

4529. Mei Rongzhao. "Liu Hui's Theories of Mathematics". In *Chinese Studies in the History and Philosophy of Science and Technology.* Edited by Fan Dainian and Robert S. Cohen. Translated by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 243-254.

Beginning with a consideration of theories of ancient Chinese mathematics, this paper goes on to describe the character of Chinese arithmetic, algebra, and geometry, and concludes with a discussion of the limitations of theory. Here the author suggests that the greatest weakness of Chinese mathematics was its lack of generalization and systematization, which he relates to problems with notation. Consequently, the author observes that there was no consideration of prime numbers or irrational numbers, nor were negative roots ever introduced.

4530. Qu Anjing. "Bian Gang: A Mathematician of the 9th Century". *Historia Scientiarum* 6 (1996), 17-30.

The author explains how Bian Gang made important contributions to calendrical research and devised the Chongxuan Calendar (892 A.D.), the last calendar of the Tang Dynasty. He also devised several new numerical algorithms in constructing his calendar, and these were of considerable influence in computing later Chinese calendars. In discussing Bian Gang's work, Qu explains the method of piecewise iterated quadratic interpolation, the use of biquadratic functions constructed via a geometric model, and the formula for calculating the varying length of the sun's shadow cast by a gnomon, which as Bian Gang proceeded involved computation of a cubic function.

4531. Salaff, Stephen. "A Biography of Hua Lo-keng [Hua Luogeng]". *Isis* 63 (1972), 143-183.

Born in 1910, Hua's reputation as a mathematician rests primarily on his many contributions to the theory of numbers. In 1936 he went to Cambridge University, where he studied with Hardy and Littlewood, among others, and did important work on the additive theory of numbers, including contributions to the Waring and Goldbach Problems. After World War II he visited the Soviet Union, where he worked with I. M. Vinogradov and made further contributions to analytic number theory. Subsequently, Hua went to the United States where he spent nearly four years at the Institute for Advanced Study and at the University of Illinois. Expanding his mathematical interests, he worked on the theory of several complex variables, automorphic functions, the geometry of matrices, differential geometry, projective geometry, and algebra. His name is associated with the Cartan–Brauer–Hua theorem, which concerns the normal subfields of a skew field.

Hua returned to China in 1950, and this article considers his subsequent career in terms of the politics of China under Mao Tse-tung. During the 100 Flowers Campaign and the Great Leap Forward, Hua turned to linear programming and applied his mathematics to the problem of threshing wheat. In 1969, at the height of the Cultural Revolution, he signed an article of self-criticism and confession in the *People's Daily* (June, 1969). He praised Mao's vision with regard to higher education and intellectual reform, and endorsed the idea of integrating factories and universities (which had been closed in 1966). As the author notes: "Hua Luogeng has thus become a representative 'reformed intellectual,' and understanding the effects of the Cultural Revolution on science and education thus calls for a critical analysis of Hua's recent intervention," (p. 144).

4532. Straffin, Philip D. "Liu Hui and the First Golden Age of Chinese Mathematics". *Mathematics Magazine* 71 (1998), 163-181.

This is an article apparently written wholly on the authority of secondary sources, or Chinese sources as translated into English. The author notes that Liu Hui's ideas are preserved in two works, his commentary on the *Jiuzhang suanshu* (263 A.D.), and in a handbook for surveying, the *Haidao suanjing* (†Sea Island Mathematical Manual†). The author's aim is not only to make students more aware of mathematics in non-Western cultures, but to show that Chinese mathematics was not simply calculational and utilitarian, but could also be theoretical and provide proofs. The article begins with a description of Chinese methods for calculating with counting rods on the counting board; it goes on to describe the *Nine Chapters*, presenting representative problems, discusses Liu Hui's commentary, especially the geometric interpretation of the square root algorithm, the dissection proofs of the *gou-gu* (or Pythagorean) theorem, then describes the †Sea Island Mathematical Manual†, and the method of reasoning it employed using similar triangles. The paper also explains Liu Hui's methods for calculating the value of pi, including an account of the even more accurate results obtained by Zu Chongzhi (429-500 A.D.), and concludes with a discussion of Liu Hui's calculations of the volume of pyramids and the volume of a sphere.

4533. Wang Yusheng. "Hua Hengfang: Forerunner and Disseminator of Modern Science in China". In *Chinese Studies in the History and Philosophy of Science and Technology.* Edited by Fan Dainian and Robert S. Cohen. Translated by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 369-394.

Hua Hengfang (1833-1902) (also known as Wanxiang and Ruoding) was a well-known mathematician, translator, and educator of the late Qing dynasty, and a forerunner and disseminator of modern science in China. As an advocate of experiment and practice, Hua is a worthy representative of those Chinese intellectuals who broke away from old academic traditions to pursue modern scientific research as it was then practiced in the West.

4534. Wang Yusheng. "Li Shanlan: Forerunner of Modern Science in China". In *Chinese Studies in the History and Philosophy of Science and Technology.* Edited by Fan Dainian and Robert S. Cohen. Translated by Kathleen Dugan and Jiang Mingshan. Dordrecht: Kluwer Academic Publishers, 1996, 345-368.

This work provides a brief account of the life and work of Li Shanlan, one of the significant transitional figures in Chinese science. Li not only understood the old Chinese science but also appreciated the power and need to learn Western approaches to the sciences as well, especially mathematics. After undertaking his own independent study of the astronomical calendar and the mathematics upon which it was based, the author confronts the question of what Li Shanlan did during the Opium War. Considerable attention is given to the important translations of geometry and mechanics on which he was working, and how Li Shanlan later assisted in the Westernization movement and "saving the nation through science."

4535. Yao Fan. (Yao Fang). *Matematik Chzhao Tszyun'tsin.* (†The mathematician Zhao Junqing†.) Moscow: VINITI, 11.04.95, dep. VINITI no. 983-B95, 23 pp.

4536. Zinin, Sergeĭ Vasil'evich. "Traktat Syuĭ Yuè kak pamyatnik nauchnoĭ i filosofskoĭ mysli Kitaya". (†Xu Yue's treatise as a monument of scientific and philosophical thought of China†.) In *Metodologicheskie problemy istoriko-nauchnykh issledovaniĭ.* (†Methodological problems of research on history of sciences†), Moscow: INION, 1985, dep. INION no. 21276, 65-71.

On Historians of Chinese Mathematics and Science

4537. Jami, Catherine. "In Memoriam. Joseph Needham (December 9, 1900–March 24, 1995)". *Historia Mathematica* 24 (1996), 1-5.

A tribute to the life and work of Joseph Needham, which notes his Marxist approach to the history of science, the origins, significance, and impact of the *Science and Civilisation in China* series, as well as Needham's special relation to history of mathematics. Jami considers what has come to be known as "the Needham puzzle": "Why did modern science—the mathematisation of hypotheses about Nature with all its implications for advanced technology—make its meteoric rise only in the West at the time of Galileo?" While acknowledging the extent to which Needham's views on history of Chinese mathematics and science have become outdated, Jami acknowledges that "one cannot but be impressed by the breadth and the sophistication of his arguments and by the encyclopedic knowledge on which he relies."

4538. Libbrecht, Ulrich. "Joseph Needham's Work In The Area Of Chinese Mathematics". *Past and Present* 87 (1980), 30-39.

This is one of three essays (the other two are on Chinese scientific philosophy and astronomy, respectively), sponsored by *Past and Present* to review Needham's encyclopedic project, *Science and Civilisation in China*. The article begins with a brief account of works on the history of Chinese mathematics before Needham, including general assessments of works by Alexander Wylie, David E. Smith, Yoshio Mikami, Louis Van Hée, Gino Loria, A. P. Yushkevich, and Èl'vira I. Berezkina among others. This is followed by a very balanced evaluation of Needham's work. Although Libbrecht points out many weaknesses, the paper holds that Needham's work is a milestone in the study of Chinese mathematics, adding that it represents the "first great synthesis."

4539. Liu Dun. "400 Years of the History of Mathematics in China—An Introduction to the Major Historians of Mathematics Since 1592". *Historia Scientiarum* 4 (1994), 103-111.

Beginning with a description of the general decline of traditional Chinese mathematics during the Ming dynasty, the author discusses the pioneering historical studies undertaken in this period by Cheng Dawei and Mei Wending. A special section is devoted to the "Qian Jia" School and the historical studies of Dai Zhen, Ruan Yuan, Li Rui, Li Huang, and Luo Shilin, all of whom were especially interested in studying and editing the classical ancient mathematical texts. Among contemporary historians of mathematics in the 20th century, the author emphasizes the important contributions of Li Yan, Qian Baocong, and Yan Dunjie.

4540. Liu Dun. "Historians of Mathematics in China". In *Historiography of History of Mathematics: Writing the History of Mathematics*. Edited by Joseph Dauben and Christoph J. Scriba. Basel: Birkhäuser, 1999.

A survey of the history of history of mathematics in China, describing the early practitioners and following their influence through the 20th century in order to account for the present vigor of the subject as currently practiced.

4541. Liu Dun. "Li Yan". In Dauben and Scriba, item 4540.

4542. Liu Dun. "Qian Baocong". In Dauben and Scriba, item 4540.

4543. Sivin, Nathan. "Current Research on the History of Science in the People's Republic of China". *Chinese Science* 3 (1978), 39-58.

This article provides a survey of research on the history of science conducted in the PRC before 1977, of which the history of Chinese mathematics is a significant part. An annotated bibliography is included.

4544. Volkov, Alekseĭ [=Alexeĭ] Karlovich. "Traktovka kitaĭskoĭ matematiki Dzh. Nidemom i ego kritikami". (†The treatment of Chinese mathematics by J. Needham and by his critics†, a review paper.)In

Sovremennye istoriko-nauchnye issledovaniya: nauka v traditsionnom Kitae. (†Modern studies in history of science: science in traditional China†.) Edited by A. I. Kobzev. Moscow: INION (Institute for Information in Social Sciences), 1987, 106-127.

A review of the "mathematical" section of the third volume of Joseph Needham's *Science and Civilisation in China* (item 4225), together with several works of modern Chinese historians of science.

4545. Wong G. "Le Professeur Li Yan". *Bulletin de l'École Française d'Extrême-Orient* 52 (1964), p. 310.

On Special Topics

4546. Bai Shangshu. "Présentation de la première trigonométrie Chinoise: *Le Dàcè*". *China Mission Studies (1550-1800) Bulletin* 6 (1984), 43-50.

This work, translated by Jean-Claude Martzloff, concerns the identification of European sources used in the composition of Chinese scientific works beginning in the 17th century. This is a necessary prelude to the evaluation of knowledge transmitted and its influence. In the past, many authors like Li Yan, Henri Bernard Maître, B. Szczeniak, P. d'Elia, and others have undertaken such studies. Unfortunately, certain Chinese works devoted to this subject, recent or not, remain unknown in the West. Therefore, a translation of this article by Bai Shangshu on the first work in Chinese devoted to trigonometry helps to redress this imbalance. The *Dàcè* was presented to the Emperor in 1631, and was based primarily on two published sources, the *Trigonometriae* of B. Pitiscus (1612) and the *Mémoirs mathématiques* of S. Stevin (1608); Bai's article shows numerous parallels between both of these works and the Chinese versions of corresponding passages in the *Dàcè*.

4547. Chemla, Karine. "La pertinence du concept de classification pour l'analyse de textes mathématiques chinois". In *Effets d'ordre dans la civilisation chinoise: rangements a l'oeuvre, classification implicités.* (*Extrême-Orient, Extrême-Occident*, 10.) Saint-Denis: Presses Universitaires de Vincennes, 1988, 61-87.

This paper suggests that by the simple act of gathering together mathematical objects, Chinese scholars were actually doing mathematics, or exemplifying some mathematical knowledge. This paper analyzes groups of objects contained in several classic Chinese mathematical treatises in order to determine their significance, not as separate objects, but as groups. Three examples are given. First, chapter seven of the *Nine Chapters on the Art of Mathematics* deals with the rule of double false position and considers problems of different kinds. Thus a unique algorithm is given to solve a variety of problems that have different relationships with it. Consequently, a mathematical task had to be performed in order to gather such problems together. A second example of how a mathematical task is required to bring different problems together is the connection Liu Hui makes among the addition of fractions, the rule of double false position, and the solution of systems of simultaneous linear equations, while proving them. The third example concerns Li Ye, who grouped formulas together in paragraphs in the *Sea Mirror of the Circle Measurements*. After analyzing the mathematical relevance of this grouping, the article concludes by emphasizing the connection between the activity of grouping mathematical objects and the recognition of analogies, both of which may reflect important mathematical insights.

4548. Chemla, Karine. “Qu’apporte la prise en compte du parallèlisme dans l’étude de textes mathématiques chinois? Du travail de l’historien á l’histoire du travail”. In *Parallèlisme de appariement des choses*. (*Extrême-Orient, Extrême-Occident*, 11.) Paris: Presses universitaries de Vincennes, 1989, 53-80.

Like any classical Chinese texts, mathematical texts also contain many parallel sentences and paragraphs. The aim of this paper is to determine how the historian of mathematics should take this feature into account. First, it is shown that such parallelisms must be considered in order to interpret texts properly. This point is illustrated by explaining how the root extraction procedures described in *Nine Chapters on the Art of Mathematics* should be understood. Secondly, the use of parallelisms is shown to have a mathematical relevance which is likely to evolve through history. This is illustrated by showing that differences between the algorithms of the *Nine Chapters* and those of the mathematical classics of Sunzi and Zhang Qiujian are reflected in differences in the distribution of parallel sentences. If these differences are not recognized, it is impossible to account for improvements that are made from the earlier to the later algorithms. Finally, a certain continuity is revealed between the mathematical work demonstrated by this change in parallelism from the *Nine Chapters* up to the mathematical treatises by Sunzi and Zhang Qiujian, and the later mathematics reflected in Jia Xian’s algorithm (11th century). The article concludes that by considering these parallelisms, it is possible to appreciate more fully the history of Chinese mathematics.

4549. Chemla, Karine. “De la synthèse comme moment dans l’histoire des mathématiques”. *Diogène* 160 (1992), 87-114.

Based on two examples, fractions and algebraic equations in the history of mathematics, this paper proposes a model for the elaboration of mathematical knowledge in terms of contrasts and syntheses. It argues that different traditions have elaborated various conceptions of what may appear today as the same objects, and that various results may occur when different conceptions happen to meet. There are examples where one conception eliminated another, as in the case of the Egyptian concept of fraction, which later disappeared as such. But there are also cases where different conceptions were synthesized, as happened when various ways of conceiving of and dealing with equations interacted with each other in the works of Arabic mathematicians.

4550. Chemla, Karine. "What is the Content of this Book? A Plea for Developing History of Science and History of Text Conjointly". *Philosophy and the History of Science. A Taiwanese Journal* 4 (2) (1995), 1-46.

Based on two examples (one taken from 13th century China—Li Ye's *Ceyuan haijing* (1248), the other from 18th-century Europe—several memoirs by Euler devoted to spherical trigonometry of polyhedra), this paper discusses why various forms of collaboration between history of science and history of texts might prove profitable. Texts are not ahistorical, transparent forms conveying meanings whose histories can be written solely on their own terms. Scientific texts as such have taken various forms within space and time, designed as they were through an interaction with local conditions of text production of all kinds. Elaborating a description of these various forms of texts would provide methodological tools to read them, since they can by no means be read without the mediation of a method. Here, the achievements of a history of texts would benefit history of science in that it would provide a better grasp of the textual contexts for the production of scientific writing, and it would give a better awareness of the various ways in which texts were meant to signify. On the other hand, the history of scientific texts could become a systematic concern in history of science as such: scientists design their texts at the same time as they design concepts and results. This represents a constitutive part of their activity, and the study of the production of texts would provide materials for better understanding how scientists benefit from the cultural and textual contexts within which they work. It would also help to show how they construct the symbolic tools with which they perform their activities and communicate their results, which in the end are texts.

4551. Chemla, Karine. "Qu'attendre de l'histoire des sciences dans les aires non-occidentales?" *Des sciences et des techniques: un débat, Cahier des Annales (EHESS)* 45 (1998), 67-83.

A discussion of a research program for studies of the so-called "Non-Western" sciences.

4552. Chemla, Karine. "The Rivers and the Sea: Analyzing Needham's Metaphor for the World History of Science". In *Situating the History of Science: Dialogues with Joseph Needham.* Edited by S. Irfan Habib and Dhruv Raina. New Delhi: Oxford University Press, 1999, 220-244.

This study analyzes in a critical way the metaphor which Joseph Needham adopted to serve as a basic historical pattern for the constitution of modern science. The paper presents evidence based on history of mathematics to argue that the pattern requires modification, and needs to be extended in various ways.

4553. Chemla, Karine, J. W. Dauben, Liu Dun, and Chikara Sasaki. "Mathematics in Asia". *Cronache. Physis. Rivista Internazionale di Storia della Scienza* 31 (1994), 563-569.

This brief report describes the rationale and content of a special symposium devoted to "Mathematics in Asia" organized by the authors specifically for the XIXth International Congress of History of Science held in Zaragoza, Spain, August 22-29, 1993. For a more detailed account, as well as a bibliography, see "Mathematics in Asia", in *XIXth International Congress of History of Science. Symposia Survey Papers-Plenary Lectures.* Edited by Jean Dhombres, Mariano Hormigón, and Elena Ausejo. Zaragoza, Spain: Gráficas Olimar, 1993, 95-100.

4554. Chemla, Karine, A. Djebbar, and Guy Mazars. "Quelques points communs dans des textes arabes, chinois, indiens". In *Histoire de fractions, fractions d'histoire.* Edited by P. Benoit, K. Chemla, and J. Ritter. Basel: Birkhäuser, 1992, 262-276.

This paper shows that a common concept of number can be found in ancient Chinese, Indian and Arabic mathematical texts. This concept of number consists of an integer plus a fraction and is represented everywhere in three lines, as it appears at the end of a division. This would mean that there was enough scientific communication for this basic component to have become common. The paper then procceds to compare the algorithms used to perform arithmetic with such numbers.

4555. Chemla, Karine, and Serge Pahaut. "Ecritures et relectures mathématiques". Postscript to the authors' French translation of Marcia Ascher, *Ethnomathematics*, under the title *Mathématiques venues d'ailleurs. Nombres, formes et jeux dans les sociétés traditionnelles.* Paris: Éditions du Seuil, 1998, 259-78.

A discussion of the theoretical relationships between ethnomathematics and history of mathematics in so-called non-Western civilizations.

4556. Dhombres, Jean. "Aperçu sur un Développement Parallèle (des mathématiques) en Chine". In *Nombre, Mesure et Continu, Epistémologie et Histoire.* Paris: Nathan, 285-304.

An introduction to history of mathematics in China.

4557. Bréard, Andrea. *Re-Kreation eines mathematischen Konzeptes im chinesischen Diskurs.* Boethius, vol. 42. Stuttgart: Franz Steiner, 1999.

The author (formerly Andrea Eberhard) analyses the history of research on series in China in a diachronical way. She shows that various traditions dealt with what we now recognize as the object "series," before a synthesis occurred in Zhu Shijie's research. A first main tradition developed in commentaries on chapter 5 of the *Nine chapters on mathematical procedures*, or in connection with it. It questions the relationship between the procedure for computing the volume of a given solid and the procedure for determining the number of objects piled in a solid of the same form. The note devoted by Shen Gua to series can be interpreted as belonging to this tradition. A second tradition, more closely connected with astronomical questions and the computation of tables, also finds some echoes in the *Nine chapters*, which reveals the astronomical flavor of some of the problems in this classic text. The synthesis performed by Zhu Shijie in terms of using the tool of the celestial unknown, is analyzed. Eberhard manages to show how the structure of the terminology used by Zhu Shijie reflects his organization of the space of series, and thus brings to light Zhu Shijie's own conception of a series. Eberhard also studies how several 19th century commentators read Zhu Shijie's main work related to series. The appendix of her thesis contains numerous translations of texts connected to series from the first until the 19th century.

4558. He Shi. "On the Li Shan-lan [Li Shanlan] Identity". In *Mots, Mélanges Offerts á M.-P. Schützenberger*. Edited by M. Lothaire. Paris: Hermès, 254-264.

4559. Jami, Catherine. "Sur l'organisation du champ des mathématiques chinoises". In *Effets d'ordre dans la civilisation chinoise: rangements a l'oeuvre, classification implicités*. (*Extrême-Orient, Extrême-Occident*, 10.) Saint-Denis: Presses Universitaires de Vincennes, 1988, 45-59.

The aim of this paper is to analyze the place and structure of mathematics in Chinese civilization. The author first looks at the position of mathematics both in the organization of knowledge and in Chinese society and institutions. She contrasts the fact that Confucian education required knowledge of mathematics with the low status of those practicing mathematics as a profession at imperial institutions such as the Board of Astronomy and the *Suanguan* (Bureau of Mathematics). Stress is laid on the fact that the introduction of scientific knowledge from the West did not do much to change this. The author then turns to a more internal perspective, to define the categories of Chinese mathematical knowledge and the composition of traditional mathematical texts. These are in turn compared with the new forms of texts which appeared once such books as Euclid's *Elements* were introduced. Jami analyses how algorithms were assigned to a particular branch of mathematics, and how these evolved through history. Her aim is to stress that Chinese knowledge was not conceived in terms of the categories that modern mathematics or science now uses. The article closes with a discussion of the organization of Chinese mathematics with respect to its foundations and the origin of mathematics.

4560. Kawahara, Hideki, and Michio Yano. "Japanese Contributions to the History of Chinese Science". *Historia Scientiarum* 6 (1996), 123-158.

See especially §1.1, pp. 123-126, devoted to mathematics. The majority of space here is devoted to the works of Yoshio Mikami. Brief mention is also made of studies Tsuruichi Hayashi devoted to Wasan, and of the contributions Matsusaburô Fujiwara made to the history of Chinese and Japanese mathematics.

4561. Liu Dun. "The Triumph of Utilitarian Mathematics". In *Tradition and Beyond. Papers from the 7th International Conference on the History of Science in East Asia, Kyoto, 2-7 August, 1993.* Edited by Keizô Hashimoto, Catherine Jami, and Lowell Skar. Osaka: Kansai University Press, 1995, 457-460.

4562. Marakuev, A. V. "Istoriya razvitiya matematiki v Kitae, a takzhe v Yaponii". (†The history of the development of mathematics in China and Japan†.) In *Otchet o deyatel'nosti matematicheskoĭ konferentsii za yanvar'-dekabr'.* (†Proceedings of the mathematical conference, January-December†.) Vladivistok, 1930, 47-60.

4563. Martzloff, Jean-Claude. "Aperçu sur l'Histoire des Mathématiques Chinoises telle qu'elle est pratiquée en République Populaire de Chine". *Historia Scientiarum* 28 (1985), 1-30.

4564. Martzloff, Jean-Claude. "Les contacts entre les astronomies et les mathématiques arabes et chinoise vues princippalement á partir des sources chinoises—état actual des connaissances". In *Deuxième Colloque Maghrébin sur l'Histoire des Mathématiques Arabes, Tunis, 1-3 Dec. 1988.* Tunis: University of Tunis I, ISEFC and ATSCM, 1991, 164-182.

4565. Mikami, Yoshio. "A Remark on the Chinese Mathematics in Cantor's *Geschichte der Mathematik*". *American Mathematical Monthly* 15 (1909), 68.

This brief note discusses methods of the abacus, which M. Cantor virtually overlooks, including use of positive and negative numbers, and various aspects of Chinese methods of solving numerical equations.

4566. Mikami, Yoshio. "Further Remarks on the Chinese Mathematics in Cantor's *Geschichte der Mathematik*". *Archiv der Mathematik und Physik* 18 (1909), 209.

In response to a passage in M. Cantor's *Geschichte* where he says (pp. 689-690) that in earlier times the Japanese were accustomed to counting numbers by the unit of *yorozu* or *nan* (10, 000), Mikami points out that the Japanese method of counting came from China via Korea. To explain how the Chinese counted numbers, Mikami draws examples from several Chinese classic mathematical books such as the *Jiu Zhang Suan Shu*, *Sun Zi Suan Jing*, and *Shu Shu Ji Yi.* As for the origins of the Chinese counting method, he notes the influence from India via the introduction of Buddhism. Meanwhile, he also corrects other errors or inaccuracies Cantor makes with respect to Chinese mathematics, among which, for instance, is the conflation of the *Shu Shu Jiu Zhang* by Qin Jiushao with the *Jiu Zhang Suan Shu*.

4567. Petitjean, Patrick, Catherine Jami, and Anne-Marie Moulin, eds. *Science and Empires. Historical Studies About Scientific Development and European Expansion*. (Boston Studies in the Philosophy of Science, vol. 136.) Dordrecht: Kluwer Academic Publishers, 1992.

4568. Sasaki, Chikara. "Asian Mathematics from Traditional to Modern". *Historia Scientiarum* 4 (1994), 69-77.

This article begins with a cultural-anthropological approach to examining mathematics in different cultures, taking Asia as a focus and considering the "non-European" roots of mathematics. It considers the impact of Western mathematics upon Asian cultures, and advocates study not only of internal characteristics of mathematics, but investigating the social status of mathematicians as well. The author concludes with the suggestion that the demarcation between Eastern and Western is basically a convention, and that mathematics should be viewed primarily as "a sincere cultural activity that has a full meaning and is contextually supported" (p. 75).

4569. Siu Man-Keung. "Pyramid, Pile, and Sum of Squares". *Historia Mathematica* 8 (1981), 61-66.

Ancient Chinese mathematicians had already noticed the connection between analogous "discrete" and "continuous" problems. The author discusses some computations carried out by Chinese mathematicians in the Song-Yuan period that can serve as "instructive examples in the mathematics classroom." Among these are formulas for $\sum n^2 = n(n+1)(2n+1)/6$. Shen Kuo (1031-1099) considers a more general case, piling problems in which the number of cannon balls in a pyramid are related to the volume of a pyramid of comparable dimensions. This is also accompanied by a suggestive "proof without words."

4570. Solomon, B. S. "One is No Number in China and the West". *Harvard Journal of Asiatic Studies* 17 (1954), 253-260.

This article focuses on the doctrine that "one is no number" enunciated by Wang Zong (1745-1794), a Chinese historian, epigrapher, bibliographer, etymologist, and calligrapher. Wang held that "One is odd, two is even. [Therefore] 1 and 2 cannot be regarded as numbers. If 1 is added to 2, the sum is 3. Therefore, 3 is the perfection of number," (p. 254). The article traces Wang's statement through earlier classical Chinese literature, and discusses its metaphysical basis. By noting that Aristotle also held similar views, and that his two works, *De Caelo* and *De Mundo* were translated into Chinese by Father François Furtado

(1587-1653) and Li Zhizao (1565-1630), the author believes that Wang's views and further developments "were inspired by the new Western scientific learning," (p. 260).

4571. Tasaka Kôdô. "An Aspect of Islam Culture Introduced into China". *Memoirs of the Research Department of the Toyo Bunko* 16 (1957), 75-160.

This work considers Islamic instruments recorded in the Tianwen zhi of the Yuan shi, as well as books and instruments recorded in the Yuan bishujian zhi. The author argues that traditional views lay too much stress on Arabic influences in China, and proposes to look carefully at the Yuan and Ming dynasties for Iranian influences in particular, noting the "flexibility and profundity of the cultural traditions of Persia."

4572. Wang Ping. "Alexander Wylie's Influence on Chinese Mathematics". In *International Association of Historians of Asia, Second Biennial Conference Proceedings*. Taipei, Taiwan Provincial Museum, 6-9 October, 1962, pg. 777–786.

4573. Yu Wang-Luen. "Knowledge of Mathematics and Science in Ching-Hua-Yüan". *Oriens Extremus* 21 (1974), 217-236.

Discusses some mathematical aspects of the novel *Ching-Hua-Yüan* (*Jinghuayuan*) by Li Ruzhen (c. 1763–1830), and presents several mathematical problems, along with oral solutions and the origins of these methods. The article reveals a general level of interest in mathematics on the part of non-scientist scholars in the early nineteenth century.

4574. Qu Anjing. "On Hypotenuse Diagrams in Ancient China". *Centaurus* 39 (1997), 193-210.

JAPAN

This bibliography does not mention all the existing modern editions of wasan texts, references to which can easily be found in Martzloff's bibliography. It only indicates the collected works of the most famous traditional mathematician, Seki Takakazu, and Shimodaira's recent project of editing the main 17th century printed mathematical treatises. As regards secondary literature, emphasis has been given to the classical studies in western languages on one hand and to the significant researches on the diffusion and the development of mathematical activity in rural areas through the 19th century on the other hand.

4575. *Sugakushi kenkyu (†Journal of History of Mathematics [in Japan])†*. Edited by Sugakushi gakkai (†The Japanese Society for the History of Mathematics)†. 1962–.

A quarterly publication, in the history of mathematics from the Edo to the Meiji period.

4576. Martzloff, Jean-Claude. "A Survey of Japanese Publications on the History of Japanese Traditional Mathematics (Wasan) from the Last 30 Years". *Historia Mathematica* (17) (4), (1990), 366-373.

A well-documented bibliography of recent publications on the subject.

4577. Endo, Toshisada, Akira Hirayama et al., eds. *Zoshu Nippon Sugakushi* (†The enlarged and revised history of Japanese mathematics†). Tokyo: Kōseisha kōseikaku, 1981, 679 + 187 pp. 1st ed., 1897. 1st revised ed., edited by Yoshio Mikami, 1918. 2nd revised and annotated ed., edited by Akira Hirayama, 1960. .

The first detailed account of the Japanese mathematical tradition. Although a little out-of-date, it is still a valuable source of information because of Endo's proximity and sensitivity to the Wasan tradition. Contains useful indexes of mathematicians' names and treatise titles as well as an almost exhaustive list of printed materials published between 1600 and 1878.

4578. Fukagawa, Hidetoshi, and Dan Pedoe. *Japanese temple geometry problems.* Winnipeg, MB.: Charles Babbage Research Centre, 1989. xvi + 206 pp.

The first English language written work entirely devoted to Japanese mathematical tablets displayed in Shinto shrines and Buddist temples throughout Japan during the Edo-period. The book contains 250 selected temple problems with their solution, a bibliography, photographs of the tablets and other relevant historical material.

4579. Hagino, Kogo. *Kyodo Sugaku no Bunken-shu* (bt Collected documents on local traditions of mathematics). Tokyo: Fuji tanki daigaku shuppanbu, 1965-66. 3 vols., 324 pp.; 422 pp.; 383 pp. .

Essays of unequal quality and interest by Mikami, Hirayama, Hagino, Oya and others, gathered and re-published for the sake of helping researchers. Most of them deal with the mathematical tablets found in provincial temples and shrines and with provincial mathematicians.

4580. Hirayama, Akira, et al., eds. *Seki Kowa Zenshu (†Takakazu Seki's collected works, edited with explanations†). Osaka: Osaka Kyoiku Tosho, 1974, 572 + 216 pp.*

All extant works of Kowa or Takakazu Seki, ranging over algebra (theory of equations, determinants), trigonometry, theory of numbers, calendrical science, and so on, with a useful analysis and English translation.

4581. Hirayama, Akira. *Takakazu Seki, sono Gyoseki to Denki* (†Takakazu Seki, his work and his life†). Tokyo: Kōseisha kōseikaku, 1974. 1st ed., 1959 316 pp.

A compact introduction to Seki Takakazu's mathematical work.

4582. Horiuchi, Annick. *Les mathématiques à japonaises l'époque d'Edo (1600-1868): une étude des travaux de Takakazu Seki (?-1708) et de Katahiro Takebe (1664-1739).* Paris: Librairie philosophique J. Vrin, 1994, 409 pp.

A new approach to the subject emphasizing the historical and intellectual background of the mathematical activity and providing at the same time a technical analysis of Seki and Takebe's research in the fields of algebra and trigonometry.

4583. Nihon Gakushiin (The Japan Academy). *Meijizen Nihon Sugakushi* (†The History of Japanese Mathematics of the pre-Meiji period†). Tokyo: Iwanami Shoten, 1954–1960, 5 vols., 443 pp.; 585 pp.; 536 pp. ; 605 pp. ; 643 pp.

A major reference book dealing with a wide range of subjects : the chronological and technical evolution of wasan methods, the development and organization of mathematical private academies, the mathematician biographies, the relations with Chinese tradition, the Western influence, and so on.

4584. Matsuzaki, Toshio. *Edo Jidai no Sokuryo-jutsu* (†The art of surveying in the Edo period†). Tokyo: Sogo kagaku Shuppan, 1979, 326 pp.

With many illustrations.

4585. Mikami, Yoshio. *The Development of Mathematics in China and Japan.* New York: G. E. Stechert & Co., 1913. Reprinted New York: Chelsea Publishing Co., 1961, 389 pp.

The first monograph written in English on the history of Japanese and Chinese mathematics.

4586. Mikami, Yoshio, and D. E. Smith. *A History of Japanese Mathematics.* Chicago: The Open Court Publishing Co., 1914.

Written in English and read by researchers around the world. But the book has many mistakes and should be revised.

4587. Mikami, Yoshio. *Bunkashi-jo yori mitaru Nihon no Sugaku* (†Japanese mathematics viewed from cultural history†). Edited by Akira Hirayama, et al. Tokyo: Kōseisha kōseikaku, 1984. 300 pp.

Contains Mikami's major papers discussing traditional mathematics in relation to the cultural background of the time as well as the social profile of the mathematicians; contains his famous theory, written in 1921, according to which the Wasan developed as a magnificent art.

4588. Nihon no Sugaku Hyakunen-shi henshu iinkai (Editorial Commitee of Nihon sugaku hyakunen shi). *Nihon no sugaku hyakunen shi* (†A

Century of Mathematics in Japan†). Tokyo: Iwanami shoten, 1983-84, 2 vols. 394 pp.; 337 pp.

A chronological account of the adoption process of western mathematics and modern scientific institutions in Japan through the past hundred years.

4589. Ogura, Kinnosuke. *Ogura Kinnosuke Chosakushu* (†Collected Works of Ogura Kinnosuke†). Tokyo: Keiso Shobo, 1973–1975. 8 vols.

Gathers Ogura's essays on mathematical education in China and Japan as well as in western countries, examined from a comparative point of view. Vol. 2 contains pioneer research on the reception of western mathematics in the Meiji period.

4590. Oya, Shinichi, et al. *Jinkoki Ronbun shu* (†Collection of papers on Jinkoki†). Osaka: Osaka kyoiku tosho, 1977, 138 pp.

A collection of papers dealing with the mathematical content, social and economical background as well as the cultural features of the most popular wasan textbook.

4591. Yoshida, Mitsuyoshi. *Jinkoki* (†The unchanging treatise†). Shinichi Oya, editor. Tokyo: Iwanami shoten, 1977, 271 pp.

An annotated edition of the most popular wasan textbook, first published in 1627.

4592. Oya, Shinichi. *Wasan izen* (†Before the Wasan†). Tokyo: Chuo Koron, 1980, 205 pp.

A well-written and compact study which sheds light on the cultural background of the growing diffusion of mathematical knowledge in medieval Japan.

4593. Sato, Kenichi, et al. *Wasanka Kazu Yamaguchi no Dochu nikki* (*The Travel Diary of the Mathematician, Kazu Yamaguchi*). Tokyo: Kenseisha, 1993, 195 pp.

A translation into modern Japanese of a 19th century mathematician's travel diary which sheds light on the wide diffusion of mathematics in rural areas and the use of mathematical tablets displayed in temples and shrines for the communication between rival schools.

4594. Shimizu, Tatsuo, et al., eds. *Suri kagaku* (†Mathematical sciences†). Vol. 12 of *Nippon Kagaku Gijutsushi Taikei* (†An outline of the history of science and technology in Japan†). Tokyo: Daiichi-hoki Shuppan, 1969, 641 pp.

Volume 12 of a massive project devoted to the history of modern science and technology in Japan. It gives general introductions to a wide range of topics such as the reception of western mathematics in the Meiji period, the creation of the department of mathematics at Tokyo university, Teiji Takagi's class field theory, the mathematical community under World War II, etc. For all topics, a wealth of historical documents, such as excerpts from textbooks, newspapers, and scientific journals of the time are appended.

4595. Shimodaira, Kazuo. *Nipponjin no Sugaku - Wasan* (†The mathematics made by the Japanese, the Wasan†). Tokyo: Kawade-shobo Shinsha, 1972, 241 + v pp.

A well-written general survey of the field.

4596. Shimodaira, Kazuo, et al., eds. Edo shoki Wasan Sensho (Selected mathematical treatises of early Edo period). Tokyo: Kenseisha, 1990–. 4 vols.

A collection of 34 treatises selected from 17th century printed materials. The editing project is not yet complete.

4597. Yamazaki, Yoemon. *Shuzan Sanpo no Rekishi* (†The history of the calculation by the abacus and counting rods†). Tokyo: Morikita Shuppan, 1958, 523 pp.

Interprets the method of calculation by the counting rods (*sangi*) and the abacus (*soroban*) in China and Japan.

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USA and Canada

4598. Albert, A. Adrian. "Leonard Eugene Dickson 1874-1954". *Bulletin of the American Mathematical Society* 61 (1955), 331–345.

A biographical article with bibliography of the twentieth-century, American algebraist, Leonard Eugene Dickson, by his student and later colleague. Dickson was a leading member of the "second generation" of American research mathematicians and established Chicago as a center of algebraic study.

4599. Archibald, Raymond Clare. "History of the American Mathematical Society, 1888–1938". *Bulletin of the American Mathematical Society* 45 (1939), 31–46.

Discusses the presidents of the American Mathematical Society and related institutional matters.

4600. Archibald, Raymond Clare. *A Semicentennial History of the American Mathematical Society, 1888–1938.* New York: American Mathematical Society, 1938. Reprinted New York: Arno Press, 1980, 262 pp.

A history of the first fifty years of the American Mathematical Society drawn from archival and published sources. It covers the Society's history; the formation of the *Bulletin*, *Transactions*, and AMS Colloquium series, the organization of various sections of the Society; the annual and summer meetings; and the holders of the various offices. In particular, it contains biographies and photographs of the first 24 AMS Presidents.

4601. Archibald, Raymond Clare. "Unpublished Letters of James Joseph Sylvester and Other New Information Concerning His Life and Work". *Osiris* 1 (1936), 85–154.

The first, major biographical study of the British algebraist and first Professor of Mathematics at The Johns Hopkins University, James Joseph Sylvester. The article presents a detailed version of Sylvester's curriculum vitae, a brief and flawed account of his stay at the University of Virginia and of the years from 1842 through 1855, a discussion of his poetry, and the transcriptions of thirty letters from Sylvester to such figures as Harvard mathematician Benjamin Peirce, editor of the *Educational Times* William J. C. Miller, and astronomer Simon Newcomb.

4602. Aspray, William. "The Emergence of Princeton as a World Center for Mathematical Research, 1896-1939". In *History and Philosophy of Modern Mathematics*. Edited by William Aspray, and Philip Kitcher. Minneapolis: University of Minnesota Press, 1988, 346–366.

An institutional analysis of the rise of Princeton University as a major center of mathematical research during the first four decades of the twentieth century. The article focuses on the innovations of Princeton President, Woodrow Wilson, and their implementation especially at the hands of mathematicians, Henry Burchard Fine and Oswald Veblen. This article was reprinted in item 4623, Part II, pp. 195-215.

4603. Bedini, Silvio A. *The Life of Benjamin Banneker*. New York: Charles S. Scribner's Sons, 1971.

Biography of the eighteenth-century, Black mathematician and surveyor, Benjamin Banneker. See also item 4621.

4604. Bell, Eric Temple. "Fifty Years of Algebra in America, 1888-1938". In *Semicentennial Addresses of the American Mathematical Society*. Edited by Raymond C. Archibald New York: American Mathematical Society, 1938, 1–34.

A survey of algebraic research in the United States from 1888 to 1938, that is, during the first fifty years of the American Mathematical Society. The author isolates eight major areas of interest to American algebraists: group theory, postulate theory, algebraic and modular invariants, the theory of equations, miscellaneous areas, and linear and abstract algebra. He provides a statistical analysis of papers published and substantive discussion of the actual research output.

4605. Bers, Lipman. "The European Mathematicians' Migration to America". In *A Century of Mathematics in America—Part I*. Edited by

Peter Duren, et al. Providence: American Mathematical Society, 1988, 231–243.

An account of the immigration into the United States of mathematicians beginning with James Joseph Sylvester's move to The Johns Hopkins University in 1876 and culminating with the many Europeans who fled the political situation in their homelands prior to and following the outbreak of World War II.

4606. Birkhoff, Garrett. "Mathematics at Harvard, 1836-1944". In *A Century of Mathematics in America—Part II.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 3–58.

A history of mathematics at Harvard from the beginning of its second century through World War II. The article focuses on the institutional contributions of Benjamin Benjamin Peirce, William Fogg Osgood and Maxime Bôcher and George David Birkhoff and concludes with the author's reminiscences of his days at Harvard first as student and then as member of the faculty.

4607. Birkhoff, George David. "Fifty Years of American Mathematics". In *Semicentennial Addresses of the American Mathematical Society.* Edited by Raymond C. Archibald New York: American Mathematical Society, 1938, 270–315.

An overview of American advances in mathematical research during the first fifty years of existence of the American Mathematical Society. After a brief discussion of the rise of research-level mathematics in the United States, the author analyzes American work in symbolic logic and axiomatics; linear algebra, finite group theory, and the theory of numbers; analysis; geometry; and applied mathematics.

4608. Birkhoff, George David. "The Scientific Work of Maxime Bôcher". *Bulletin of the American Mathematical Society* 25 (1919), 197–215.

A retrospective article on the mathematical research achievements of Harvard mathematician, Maxime Bôcher by one of his undergraduate students and later colleague. A student of Felix Klein, Bôcher, brought his research agenda back to Harvard and was instrumental in establishing one of America's major research departments there. This article was reprinted in item 4623 Part II, pp. 59–78. Compare item 4659.

4609. Bliss, Gilbert Ames. "Eliakim Hastings Moore". *Bulletin of the American Mathematical Society*, 2d. ser. 39 (1933), 831–838.

A biographical article on University of Chicago mathematician, Eliakim Hastings Moore, by his colleague. Moore was the Head of the first Department of Mathematics at Chicago and an early shaper of the American mathematical research community. See also item 4611.

4610. Bliss, Gilbert Ames. "Oskar Bolza—In Memoriam". *Bulletin of the American Mathematical Society* 50 (1944), 478–489.

A biographical article with bibliography of University of Chicago mathematician, Oskar Bolza, by his student. Bolza was a member of the first Department of Mathematics at Chicago and established a tradition there in the calculus of variations.

4611. Bliss, Gilbert Ames. "The Scientific Work of Eliakim Hastings Moore". *Bulletin of the American Mathematical Society* 40 (1934), 501–514.

A companion article to item 4609, this analyzes the research in algebra, foundations, and analysis of University of Chicago mathematician, Eliakim Hastings Moore, and provides a bibliography of his works.

4612. Bolza, Oskar. "Heinrich Maschke: His Life and Work". *Bulletin of the American Mathematical Society* 15 (1908), 85–95.

A biographical article on the University of Chicago mathematician, Heinrich Maschke, by his friend and colleague. Maschke, together with E. H. Moore and Oskar Bolza, was a member of the first Department of Mathematics at Chicago and worked to establish an early tradition there in geometry. This paper also analyzes Maschke's works and provides a bibliography.

4613. Borel, Armand. "The School of Mathematics at the Institute for Advanced Study". In *A Century of Mathematics in America—Part III*. Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 119–148.

An historical study of the formation and development of the School of Mathematics at the Institute for Advanced Study in Princeton from its founding in 1930 through the 1980s. The author, himself a Professor at the Institute, draws from archival and published sources as well as personal experience in documenting the evolution of the School of Mathematics.erv

4614. Bruce, Robert V. "A Statistical Profile of American Scientists, 1846-1876". In *Nineteenth-Century American Science: A Reappraisal*. Edited by George H. Daniels Evanston: Northwestern University Press, 1972, 63–94.

A valuable statistical analysis of American science, including mathematics, during the three decades from 1846 to 1876. The author provides demographic data on the various kinds of scientists such as birth place, amount of education, father's occupation, etc.

4615. Cajori, Florian. *The Teaching and History of Mathematics in the United States*. Washington, D.C.: Government Printing Office, 1890, 400 pp.

Far-reaching survey of American mathematics through the late 19th century. Covers English and later French influences, textbooks, journals, leading mathematicians, attitudes towards fluxional and differential calculus, and all levels of mathematical education. Especially interesting are statistical results of a survey on mathematical education conducted by the U.S. Bureau of Education in the late 19th century. Abundant references in text, footnotes, and an appended bibliography on American calculus enhance the work's usefulness as a beginning research tool. No index.

4616. Charbonneau, Louis. "Mathematics: History in Canada". In J. H. Marsh, ed., *The Canadian Encyclopedia*, Edmonton: Hurtig, 1988, 1098–1099.

4617. Cooke, Roger, and V. Frederick Rickey. "W. E. Story of Hopkins and Clark". In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 29–76.

An historical study of the role that William E. Story played first in helping J. J. Sylvester set up and run America's first research program in mathematics at The Johns Hopkins University, then in maintaining the program following Sylvester's departure in December 1883 until 1889, and finally in building and sustaining the initially purely graduate program at Clark University from its founding in 1889. The article also has a list of students who earned graduate degrees at Clark between 1889 and 1921 and examines the "crisis" in 1892 that preceded William Rainey "Harper's raid" of the Clark faculty for his new faculty at the University of Chicago.

4618. Coolidge, Julian. "Robert Adrain, and the Beginnings of American Mathematics". *American Mathematical Monthly* 33 (1926), 61–76.

A look at the Irish-born mathematician, Robert Adrain, his independent (of Gauss) discovery the law of least squares, and his efforts throughout the first quarter of the nineteenth century to sustain mathematical journals in the United States.

4619. Dahan Dalmedico, Amy. "L'Essor des mathématiques appliquées aux États-Unis: L'Impact de la Seconde Guerre Mondiale". *Revue d'Histoire des Mathématiques* 2 (1996), 149–213.

A study of the impact of World War II on the development of the field of applied mathematics in the United States. The paper focuses on the role that the wartime mobilization of mathematicians had on the definition of fields of applied mathematics. It also examines the postwar institutionalization of applied mathematics especially at the Courant Institute. Compare item 4660.

4620. Dauben, Joseph W. *Abraham Robinson: The Creation of Nonstandard Analysis A Personal and Mathematical Odyssey.* Princeton: Princeton University Press, 1995, xix + 559 pp.

A biography of the founder of nonstandard analysis, Abraham Robinson, that interweaves the story of Robinson's turbulent life and the development of his mathematical thought, both pure and applied. A political refugee, Robinson fled Germany in 1933, lived in Palestine from 1933 to 1939, studied in Paris in 1940, and spent the years from 1940 until 1951 in London. The book tracks Robinson throughout these peregrinations and analyzes the work he did in mathematics as well as in aeronautics and philosophy. It also provides valuable insights into such twentieth-century institutional settings as the University of Toronto, the Hebrew University in Jerusalem, the University of California at Los Angeles, and Yale University, the universities at which Robinson taught from 1951 until his death in 1974.

4621. Donaldson, James A. "Black Americans in Mathematics". In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 449–469.

An overview of Black mathematicians in the United States, beginning with the eighteenth-century surveyor, Benjamin Banneker, and closing with thoughts on prospects for the future. The article discusses the careers of a number of prominent twentieth-century Black mathematicians.

4622. Dorwart, Harold. "Mathematics and Yale in the Nineteen Twenties". In *A Century of Mathematics in America—Part II.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 87–98.

A Yale graduate student in the 1920s recalls the Mathematics Department during that decade, a period during which Yale became a major research-oriented department. Among the mathematicians discussed are James Pierpont, Ernest W. Brown, and Percey F. Smith.

4623. Duren, Peter, et al., eds. *A Century of Mathematics in America—Parts I-III.* (History of Mathematics.) Providence: American Mathematical Society, 1988-1989. 3 vols. Part I, viii + 477 pp.; Part II, x + 585 pp.; Part III, ix + 675 pp.

A three-volume collection of new and reprinted essays and articles (with no indices) on the history of mathematics in the United States commemorating the hundreth anniversary of the founding of the American Mathematical Society. A number of the articles in these volumes are abstracted here. See items 4602, 4608, 4613, 4617, 4621, 4622, 4630, 4631, 4641, 4645, 4646, 4648, 4649, 4654, 4655, 4663, 4674, 4678, 4679, 4681, 4682, 4694, 4699, and 4703.

4624. Feffer, Loren Butler. "Mathematical Physics and the Planning of American Mathematics: Ideology and Institutions". *Historia Mathematica* 24 (1997) 66–85.

This paper explores the ambiguous relationship between pure mathematics and mathematical physics in the American mathematical research community from its founding in the 1880s through the end of World War I. After the First World War, mathematicians such as Princeton's Oswald Veblen realized that pure mathematics could benefit from a closer alignment with mathematical physics, especially in light of the latter's association with the "new physics" that was attracting so much popular attention.

4625. Fenster, Della Dumbaugh. "Role Modeling in Mathematics: The Case of Leonard Eugene Dickson (1874-1954)". *Historia Mathematica* 24 (1997), 7–24.

An analysis of the University of Chicago algebraist, Leonard Eugene Dickson, as an adviser of doctoral students. The paper focuses on such Dickson students as A. Adrian Albert, Mina Rees, and Olive Hazlett and argues that Dickson functioned as a role model—as opposed to a mentor—for his students.

4626. Fenster, Della Dumbaugh, and Karen Hunger Parshall. "A Profile of the American Mathematical Research Community, 1891–1906". In *The History of Modern Mathematics.* Vol. 3. Edited by Eberhard Knobloch, and David E. Rowe. Boston: Academic Press, Inc., 1994, 179–227.

A compilation and analysis of data on the American mathematical research community retrieved from the first fifteen volumes of the *Bulletin of the American Mathematical Society* and from James McKeen Cattell 's *American Men of Science*. The authors uncover over a thousand participants in research-level mathematics in the United States and look at those participants from the point of view of education, employment, geographical distribution, mathematical interests, and overall participation in the community. See also the companion article on women in the early research community, item 4627.

4627. Fenster, Della Dumbaugh, and Karen Hunger Parshall. "Women in the American Mathematical Research Community, 1891–1906". Iin *The History of Modern Mathematics*. Vol. 3. Edited by Eberhard Knobloch, and David E. Rowe. Boston: Academic Press, Inc., 1994, 229–261.

A companion article to item 4626 that focuses specifically on the 71 women who formed part of the American mathematical research community between 1891 and 1906. The authors first explore some of the difficulties women experienced in attaining the research level in mathematics around the turn of the twentieth century and then turn to

an analysis of the level of participation of women in the American Mathematical Society. They focus on the lives and careers of the 18 women most actively involved, among them Ida May
Ida May Schottenfels, Mary Francis Winston (later Newson), and Charlotte Angas Scott.

4628. Feuer, Lewis S. "America's First Jewish Professor: James Joseph Sylvester at the University of Virginia". *American Jewish Archives* 36 (1984), 151–201.

An indepth look at James Joseph Sylvester's four-and-a-half-month tenure as Professor of Mathematics at the University of Virginia (1841–1842). Many stories have been told about this stay, generally involving a physical attack either of Sylvester by a student or vice versa followed by Sylvester's resignation and flight from Charlottesville. The author analyzes Sylvester's stay in the broader context of student unrest and anti-Semitism in light of the records that remain.

4629. Fillmore, Peter. ed. *Canadian Mathematical Society. 1945–1995.* Vol. 1. *Mathematics in Canada.* Ottawa, ON: Canadian Mathematical Society, 1995.

Contains historical articles. Especially significant are:
Thomas Archibald and Louis Charbonneau, "Mathematics in Canada before 1945: A Preliminary Survey", pp. 1–90; G. F. D. Duff, "The Second Generation: A History of the Canadian Mathematical Society 1966–1995". pp. 129–189; and Martine Foisy and Yves Gingras, "Emergence et evolution de la recherche en mathématiques au Quebec, 1945–1984", pp. 191–209.

4630. Fiske, Thomas Scott. "Mathematical Progress in America". *Bulletin of the American Mathematical Society* 11 (1905), 238–246.

A brief survey of mathematics in the United States by the founder of the American Mathematical Society, Thomas Fiske, on the occasion of his assuming the Society's presidency in December of 1904. This article is reprinted in Part I of item 4623, pp. 3–11.erv

4631. Gorenstein, Daniel. "The Classification of the Finite Simple Groups. A Personal Journey: The Early Years". In *A Century of Mathematics in America—Part I.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1988, 447–476.

An account of the early years of the classification of the finite simple groups by the principal architect of the program that ultimately led to the solution. Gorenstein traces the early history of the research effort from the Air Force Cambridge Research Center in the mid 1950s where he first heard of the problem, to the group theory year organized by Adrian Albert at the University of Chicago in 1960-1961, through Gorenstein's Chicago lecture of July 1972 in which he sketched the 16-step program for the classification.

4632. Grabiner, Judith V. "Mathematics in America: The First Hundred Years". In *The Bicentennial Tribute to American Mathematics, 1776-1976*. Edited by Dalton Tarwater. Washington, D.C.: The Mathematical Association of America, 1977, 9–24.

An analysis of the American mathematical landscape from 1776 to 1876 focusing on the institutional factors affecting the development of mathematics in the United States. The author argues that the advances after 1876 very much depended on the groundwork laid in the country's first hundred years.

4633. Green, Judy, and Jeanne LaDuke. "Women in the American Mathematical Community: The Pre-1940 Ph.D.'s". *The Mathematical Intelligencer* 9 (1) (1987), 11–23.

A look at those American women who earned the Ph.D. prior to 1940.

4634. Heims, Steve J. *John von Neumann and Norbert Wiener*. Cambridge, MA: The MIT Press, 1980.

A dual biography of two of the mid-twentieth century's most influential mathematicians, John von Neumann and Norbert Wiener.

4635. Hogan, Edward R. "George Baron and the *Mathematical Correspondent*". *Historia Mathematica* 3 (1976), 403–415.

A brief study of the earliest American journal devoted solely to mathematics, the *Mathematical Correspondent*, and its founding editor, George Baron. The journal lasted only through nine issues which came out between 1804 and 1806.

4636. Hogan, Edward R. "The Mathematical Miscellany (1836–1839)". *Historia Mathematica* 12 (1985), 245–257.

A brief look at the American journal, *The Mathematical Miscellany*, which was edited by Charles Gill from 1836 to 1839. Among its contributors were Harvard mathematician, Benjamin Peirce, and Rutgers professor, Theodore Strong.

4637. Hogan, Edward R. "Robert Adrain: American Mathematician". *Historia Mathematica* 4 (1977), 157–172.

Biographical article on the Irish-born emigré, Robert Adrain. Compare also item 4618.

4638. Hogan, Edward R. "Theodore Strong and Ante-Bellum American Mathematics". *Historia Mathematica* 8 (1981), 439–455.

Looks at the life, career, and work of Rutgers University professor of mathematics, Theodore Strong. Antebellum America was not known for its overall mathematical sophistication, but Strong brought a certain familiarity with European sources to bear in his work on elementary number theory, trigonometry, and synthetic Euclidean geometry. In so doing he brought some of those European ideas before American mathematicians. Strong is also notable as a teacher of mathematical astronomer, George William Hill.

4639. Hunter, Patti Wilger. "Drawing the Boundaries: Mathematical Statistics in 20th-Century America". *Historia Mathematica* 23 (1996), 7–30.

An analysis of the process of disciplinary delineation that resulted in the formation of the field of mathematical statistics—as distinct from statistics as a purely quantitative tool—in the United States. The author looks at the distancing of the new breed of mathematical statisticians from the statisticians in the social sciences as reflected in the founding of the journal, the *Annals of Mathematical Statistics*, and of the Institute of Mathematical Statistics in the 1930s. She also examines the impact of World War II on the development of new mathematical statistical techniques such as sequential sampling.

4640. Jacobson, Nathan. *Collected Mathematical Papers*. Boston/Basel/Berlin: Birkhäuser Boston, 1989. 3 vols. Vol. 1, xviii + 454 pp.; Vol. 2, xviii + 556 pp.; Vol. 3, xviii + 596 pp.

This collection reprints the collected mathematical papers of the American algebraist, Nathan Jacobson. Volume 1 covers the years from 1934 to 1946, volume 2 from 1947 to 1965, and volume 3 from 1965 to 1988. Each volume also contains autobiographical essays that provide a unique glimpse into twentieth-century American mathematics. Three different photographs of Jacobson are included as is a list of his doctoral students and a chronology of his career.

4641. Kaplansky, Irving. "Abraham Adrian Albert". *Biographical Memoirs of the National Academy of Sciences*. 51 (1980), 3–22.

A biographical article on one of America's premier algebraists, the University of Chicago mathematician A. Adrian Albert. It includes a photograph of Albert, a list of his doctoral students, and his complete bibliography. This article is reprinted in item 4623 Part I, pp. 244-264.

4642. Karpinski, Louis C. *Bibliography of Mathematical Works Printed in America through 1850.* Ann Arbor: University of Michigan Press; London: Oxford University Press, 1940. Reprinted with supplementary material New York: Arno, 1980.

Covers books, pamphlets, broadsides, encyclopedias, reference works, journals, and newspapers with mathematical articles. Entries are arranged chronologically according to first editions. Annotations provide information on multiple editions of works, where appropriate, and list libraries holding copies of cited materials. The works are indexed according to authors and subjects. Additional indexes of printers and publishers and of non-English and Canadian works are included. Over 600 facsimiles of title or other pages of cited materials complement the text.

4643. Kenschaft, Patricia C. "Charlotte Angas Scott (1858-1931)". In *Women of Mathematics: A Biobibliographic Sourcebook*. Edited by Louise S. Grinstein, and Paul J. Campbell. New York: Greenwood Press, 1987, 193–203.

A biographical article on an early, influential woman in American mathematics, the English-born Charlotte Angas Scott. Scott was Professor of Mathematics at Bryn Mawr College, where she supervised the doctoral work of seven students.

4644. Kevles, Daniel J. "The Physics, Mathematics, and Chemistry Communities: A Comparative Analysis". In *The Organization of Knowledge in Modern America, 1860–1920*. Edited by Alexandra Oleson, and John Voss. Baltimore: The Johns Hopkins University Press, 1980, 139–172.

As the title suggests, this paper is a comparative analysis of the emergent communities of physicists, mathematicians, and chemists during the closing three decades of the nineteenth century. It focuses on the formation of specialized journals and societies and the creation of research-oriented universities and explores the problems faced by these scientists in late-nineteenth-century America.

4645. Lefschetz, Solomon. "Reminiscences of a Mathematical Immigrant in the United States". *American Mathematical Monthly* 77 (1970), 344–350.

A brief but informative synopsis of Lefschetz's education and of his institutional affiliations as a professor of mathematics. Little discussion of his research. [This article is reprinted in item 4623 Part I, pp. 201–207.]

4646. Lewis, Albert C. "The Building of the University of Texas Mathematics Faculty, 1883-1938". In *A Century of Mathematics in America-Part III*. Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 205–239.

This article looks at the formation of the Department of Mathematics at the University of Texas in Austin. It concentrates on the roles of such figures as George Bruce Halsted, M. B. Porter, H. Y. Benedict, Robert L. Moore, and Harry S. Vandiver.

4647. Lewis, Albert C. "George Bruce Halsted and the Development of American Mathematics". In *Men and Institutions in American Mathematics*. Edited by J. Dalton Tarwater, John T. White, and John D. Miller (Graduate Studies, Texas Tech University, 13.) Lubbock: Texas Tech Press, 1976, 123–129.

A look at the life, career, and mathematical interests of George Bruce Halsted, student of James Joseph Sylvester at The Johns Hopkins University and early proponent of non-Euclidean geometry in the United States.

4648. Mac Lane, Saunders. "Mathematics at the University of Chicago: A Brief History". In *A Century of Mathematics in America—Part II.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 127–154.

A study of the Mathematics Department at the University of Chicago from its founding in 1892 by E. H. Moore, Oskar Bolza, and Heinrich Maschke to the so-called "Stone Age" of the 1950s when Marshall Stone revivified the program. It provides the names and ranks of the faculty members, glimpses at the curriculum, and thoughts on what makes a "good department."

4649. Mac Lane, Saunders. "The Applied Mathematics Group at Columbia in World War II". In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 495–515.

This article focuses on the Applied Mathematics Group that did war-related mathematical work at Columbia during World War II. It covers that group's work in aerodynamics, the calibration of gunsights, and operations research and closes with a list of the group's research staff, computing staff, and administrative staff. Compare item 4660.

4650. Macrae, Norman. *John von Neumann: The Scientific Genius Who Pioneered the Computer, Game Theory, Nuclear Deterrence, and Much More.* New York: Pantheon Books, 1992, x + 405 pp.

A non-technical biography of John von Neumann that explores his early work on computers and in game theory and that examines his broader social concerns.

4651. Masani, Pesi R. *Norbert Wiener, 1894-1964.* (Vita Mathematica, 5.) Basel: Birkhäuser Verlag, 1990.

A biography of the mathematical prodigy, Norbert Wiener. Compare item 4702.

4652. May, Kenneth O., ed. *The Mathematical Association of America: Its First Fifty Years.* Washington, D.C.: The Mathematical Association of America, 1972, vii + 172 pp.

This institutional history contains six essays: the background to the founding of the M.A.A. (P. S. Jones), its first quarter-century (C. B. Boyer), its role during the Second World War (E. P. Starke), and during the next two decades (H. F. Montague), as well as its financial history (H. M. Gehman). The final third of the volume consists of ten appendices, with data and brief histories on such topics as the *Mathematics Magazine* and the Putnam Competition, by G. H. Moore. See also items 3942 and 2347.

4653. McClintock, Emory. "The Past and Future of the Society". *Bulletin of the American Mathematical Society* 1 (1895), 85–94.

A look at the early history of the New York Mathematical Society—just following its name change to the American Mathematical Society in 1894—by Society President Emory McClintock. McClintock outlines what he sees as the future goals of the organization: the promotion of the study of mathematics, the publication of mathematical research, and the encouragement of mathematics teaching and of textbook writing.

4654. Merzbach, Uta C. "The Study of the History of Mathematics in America: A Centennial Sketch". In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 639–666.

An overview of work done in the United States on the history of mathematics from the publication of Florian Cajori's book (see item 4615) on *The Teaching and History of Mathematics in the United States* in 1890 to the late 1960s with brief indication as to the scene up to the late 1980s. Special mention is made of the work of David Eugene Smith, Louis Karpinski, Raymond Clare Archibald, Dirk Struik, and Otto Neugebauer among others.

4655. Montgomery, Deane. "Oswald Veblen". *Bulletin of the American Mathematical Society* 69 (1963), 26–36.

An obituary which emphasizes Veblen's education and institutional affiliations, with a brief discussion of his contributions to projective and differential geometry. (This was also reprinted in item 4623 Part I, pp. 118–129.)

4656. Mordell, L. J. "Reminiscences of an Octogenarian Mathematician". *American Mathematical Monthly* 78 (1971), 952–961.

Anecdotal reminiscences of the education and career of the eminent number-theorist L. J. Mordell.

4657. Morse, Marston. "George David Birkhoff and his Mathematical Work". *Bulletin of the American Mathematical Society* 52 (1946), 357–391.

A biographical article on Harvard mathematician, George David Birkhoff that focuses on an analysis of his work in differential equations, dynamical systems, and ergodic theory.

4658. Newcomb, Simon. "Exact Science in America". *North American Review* 119 (1874), 286–308.

An analysis of the state of the exact sciences in America in 1874 by outspoken astronomer, Simon Newcomb. Relative to mathematics, Newcomb finds the "prospect . . . here about as discouraging as the retrospect [p. 288]." Ironically, he is writing two years prior to the founding of The Johns Hopkins University which would begin the process of establishing research-level mathematics in the United States.

4659. Osgood, William Fogg. "The Life and Services of Maxime Bôcher". *Bulletin of the American Mathematical Society* 25 (1919), 337–350.

An appreciation of Harvard mathematician, Maxime Bôcher, by his friend and colleague, William Fogg Osgood. Together with Osgood, Bôcher created a research-oriented Department of Mathematics at Harvard in the early years of the twentieth century. Compare item 4608.

4660. Owens, Larry. "Mathematicians at War: Warren Weaver and the Applied Mathematics Panel, 1942-1945". In *The History of Modern Mathematics*. Edited by David E. Rowe, and John McCleary. Boston: Academic Press, Inc., 1989, 2 vols. 287–305.

An analysis of the Applied Mathematics Panel headed by Warren Weaver and its role in mobilizing mathematicians for the war effort during World War II.

4661. Parshall, Karen Hunger. "America's First School of Mathematical Research: James Joseph Sylvester at The Johns Hopkins University 1876-1883". *Archive for History of Exact Sciences* 38 (1988), 153–196.

An analysis of America's first research-level program in mathematics that focuses first on trends in American higher education, then narrows in on the particular institutional setting of The Johns Hopkins University, and finally closes in on the formation of the mathematics program, principally by James Joseph Sylvester, as well as on the actual combinatorial research that Sylvester and his students did.

4662. Parshall, Karen Hunger. "A Century-Old Snapshot of American Mathematics". *The Mathematical Intelligencer* 12 (3) (1990), 7–11.

A look back at some of the findings that Florian Cajori presented in his book, *The Teaching and History of Mathematics in the United States* (see item 4615), on the hundredth anniversary of the book's publication.

4663. Parshall, Karen Hunger. "Eliakim Hastings Moore and the Founding of a Mathematical Community in America, 1892-1902". *Annals of Science* 41 (1984), 313-333.

This paper focuses on the activities of Eliakim Hasting Moore and the Department of Mathematics at the University of Chicago. Founded in 1892, the University took as part of its mission the production and publication of original research and the training of future researchers. The first head of its Department of Mathematics, E. H. Moore, realized these goals relative to mathematics, establishing Chicago as the American center for mathematical research and mathematical activism in the two decades around 1900. This paper is also reprinted in item 4623 Part II, pp. 155-175.

4664. Parshall, Karen Hunger. “In Pursuit of the Finite Division Algebra Theorem and Beyond: Joseph H. M. Wedderburn, Leonard E. Dickson, and Oswald Veblen”. *Archives internationales d’Histoires des Sciences* 33 (1983), 274–299.

This article focuses on Joseph H. M. Wedderburn’s year as a visiting Carnegie Fellow at the University of Chicago, 1904–1905. During that year and in that vibrant research environment, Wedderburn was in competition with University of Chicago professor, Leonard E. Dickson, for the result that Wedderburn would ultimately get, namely, the finite division algebra theorem. Wedderburn and Chicago graduate student, Oswald Veblen, applied the result to construct finite non-Desarguian and non-Pascalian geometries.

4665. Parshall, Karen Hunger. “Joseph H. M. Wedderburn and the Structure Theory of Algebras”. *Archive for History of Exact Sciences* 32 (1985), 223–349.

A detailed, mathematical account of the history of Joseph H. M. Wedderburn’s ground-breaking structure theory of algebras, published in 1907. Drawing on work from many sources, including research done by Benjamin Peirce at Harvard and James Joseph Sylvester at The Johns Hopkins University, Wedderburn essentially formulated his theory during his year from 1904 to 1905 as a visiting Carnegie Fellow at the University of Chicago (compare item 4664.

4666. Parshall, Karen Hunger. “Mathematics in National Contexts (1875-1900): An International Overview”. In *Proceedings of the International Congress of Mathematicians: Zürich*. Edited by S. Chatterji. Basel/Boston/Berlin: Birkhäuser Verlag, 1995, 2 vols. 1581–1591.

A comparative analysis of the development of research-level mathematics in Germany, France, Italy, Spain, Russia, Great Britain, and the United States during the closing quarter of the nineteenth century. The author documents that, regardless of national context, educational reforms (most often guided by a perception of the Prussian system of higher education), the adoption of original research and publication as part of the mission of the academic mathematician, the training of future researchers, and the development of lines of communication such as journals and mathematical societies characterized the professionalization of mathematics internationally between 1875 and 1900.

4667. Parshall, Karen Hunger. “New Light on the Life and Work of Joseph Henry Maclagan Wedderburn (1882-1948)”. In *Amphora: Festschrift für Hans Wussing zu seinem 65. Geburtstag*. Edited by Menso Folkerts, et al. Basel/Boston/Berlin: Birkhäuser Verlag, 1992, 523–537.

A biographical article on the Scottish-born, Princeton algebraist, Joseph H. M. Wedderburn. Compare items 4664 and 4665.

4668. Parshall, Karen Hunger. "A Study in Group Theory: Leonard Eugene Dickson's *Linear Groups*". *The Mathematical Intelligencer* 13 (1) (1991), 7–11.

A look at the early work of University of Chicago graduate student and later professor, Leonard Eugene Dickson, on the theory of linear groups. Extending the research he presented in his 1896 doctoral dissertation into the book-length study, *Linear Groups with an Exposition of the Galois Field Theory* published by the distinguished German firm B. G. Teubner in 1901, Dickson demonstrated that Americans were doing important research-level work at the turn of the century.

4669. Parshall, Karen Hunger, and David E. Rowe "Embedded in the Culture: Mathematics at the World's Columbian Exposition of 1893". *The Mathematical Intelligencer* 15 (2) (1993), 40–45.

Focuses on the Mathematical Congress that took place as part of the World's Columbian Expostion in Chicago in 1893. That Congress, organized by the mathematicians at the University of Chicago—E. H. Moore, Oskar Bolza, and Heinrich Maschke—together with Northwestern professor Henry Seely White, represented mathematics as on a par culturally with the art, architecture, and technology so much in evidence at the fair.

4670. Parshall, Karen Hunger, and David E. Rowe *The Emergence of the American Mathematical Research Community, 1876-1900: J. J. Sylvester, Felix Klein, and E. H. Moore.* (History of Mathematics, 8.). Providence: American Mathematical Society; London: London Mathematical Society, 1994, xxiv + 500 pp.

An indepth analysis of the rise of research-level mathematics and mathematical community during the final quarter of the nineteenth century. The book opens with a chapter on the American scene from 1776 to 1876 that shows mathematics as situated within the broader context of American science. It moves in the next eight chapters to document the professionalization of mathematics *per se*, focusing on the roles of James Joseph Sylvester at The Johns Hopkins University, Felix Klein principally at Göttingen University, and Eliakim Hastings Moore at the University of Chicago. These chapters focus closely on the institutional settings as well as on the actual mathematical research and broader organizational activities done in those settings. The book closes with a chapter sketching the contours of what the authors call the "period of consolidation and growth" in American mathematics, namely the period from 1900 to World War II.

4671. Pitcher, Everett. *A History of the Second Fifty Years: American Mathematical Society 1939–1988.* (American Mathematical Society

Centennial Publications, 1.). Providence: American Mathematical Society, 1988.

An archivally based look at the history of the American Mathematical Society from 1939 to 1988 intended as a follow-up to Raymond C. Archibald's history of the first fifty years of the Society (compare item 4600).

4672. Pycior, Helena M. "Benjamin Peirce's 'Linear Associative Algebra'". *Isis* 70 (1979), 537–551.

A mathematical, philosophical, and historical analysis of Benjamin Peirce's ground-breaking work of 1870 on the theory of linear associative algebra. In that work, Peirce developed the notions of idempotent and nilpotent elements as well as the so-called Peirce decomposition of an algebra. See also item 4665. For further information on Benjamin Peirce see 2329 and 2331.

4673. Pycior, Helena M. "British Synthetic vs. French Analytic Styles of Algebra in the Early American Republic". In *The History of Modern Mathematics*. Edited by David E. Rowe, and John McCleary. Boston: Academic Press, Inc., 1989, 2 vols. Vol. 1, 125–154.

A study principally of four American algebra textbooks: Jeremiah Day's *Introduction to Algebra* (1814), John Farrar's series of translations of French texts (from the 1820s), Charles Davies's edition of Bourdon's *Elements of Algebra* (1835), and Benjamin Peirce's *Elementary Treatise on Algebra* (1837). The author traces the influences (or lack thereof) of the British synthetic and the French analytic styles of presentation.

4674. Rees, Mina. "The Mathematical Sciences and World War II". *American Mathematical Monthly* 87 (1980), 607–621.

A look at the mobilization of mathematicians during World War II. This paper was reprinted in item 4623 Part I, pp. 275–289.

4675. Reid, Constance. *Courant in Göttingen and New York: The Story of an Improbable Mathematician*. New York: Springer-Verlag, 1976. 314 pp. See item 2392.

4676. Reid, Constance. *Neyman—From Life*. New York: Springer-Verlag, 1982.

A non-technical biography of the statistician, Jerzy Neyman.

4677. Reid, Constance. *The Search for E. T. Bell Also Known As John Taine*. Washington, D.C.: Mathematical Association of America, 1993. x + 372 pp.

A biography of the twentieth-century, American number theorist and well-known author of *Men of Mathematics*, Eric Temple Bell. (Under the pseudonym, John Taine, Bell also wrote science fiction.) The author describes the twists and turns of her efforts to pin down Bell's biographical details. The book contains numerous photographs.

4678. Reingold, Nathan. "Refugee Mathematicians in the United States of America, 1933-1941: Reception and Reaction". *Annals of Science* 38 (1981), 313–338.

A study of the mathematicians who fled the political situation in Europe beginning in 1933 and their impact on research-level mathematics in the United States. The author details the efforts of American mathematicians like the Institute for Advanced Study's Oswald Veblen and Brown University's R. G. D. Richardson to place these refugees as well as the problems they subsequently encountered. This article was reprinted in item 4623, Part I, pp. 175–200.

4679. Rider, Robin. "An Opportune Time: Griffith C. Evans and Mathematics at Berkeley". In *A Century of Mathematics in America—Part II.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 283–302.

An analysis of the rise of the University of California at Berkeley as a major force in research-level mathematics in the United States. The author focuses on the role of departmental chair (from 1933 to 1949), Griffith C. Evans, in that development. Working under a supportive administration, Evans was able capitalize on the influx of European refugee mathematicians (compare item 4678), bringing Hans Lewy in differential equations and statistician Jerzy Neyman (compare item 4676) to Berkeley.

4680. Roberts, David L. "Albert Harry Wheeler (1873-1950): A Case Study in the Stratification of American Mathematical Activity". *Historia Mathematica* 23 (1996), 269–287.

Focusing on the career of Clark University-trained, high school mathematics teacher, Albert Harry Wheeler, the author analyzes three levels of mathematical appreciation in the United States during the first half of the twentieth century: the "highbrow" research level, the "middlebrow" level of the mathematical enthusiast, and the "lowbrow" level of the general public. Through his work on polyhedra and on the construction of mathematical models, Wheeler appealed to and participated in mathematics at all three of these levels.

4681. Rosenstein, George M., Jr. "The Best Method. American Calculus Textbooks of the Nineteenth Century". In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 77–109.

A study of American calculus textbooks published during the nineteenth and early twentieth centuries. The author documents the changing ways in which calculus was presented, beginning with the translations of French texts by Harvard's John Farrar in the 1820s and following through to the well-known text by William Granville, Percey Smith, and William Longley first published in 1904. He focuses on the presentation of such key concepts as the limit and infinitesimals and analyzes the textbook authors and their pedagogical goals. The article closes with a bibliography of American calculus textbooks published between 1828 and 1920.

4682. Royden, Halsey. "A History of Mathematics at Stanford". In *A Century of Mathematics in America—Part II*. Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 237–277.

A look at the evolution of mathematics at Stanford University from its founding in 1891 through the 1960s. The author divides the later history of the department into the "Blichfeldt years" and the "Szegö period." Group theorist Hans Blichfeldt chaired the department from 1927 until 1938 and oversaw Stanford's move into mathematical statistics and mathematical economics with the appointments of Harold Hotelling and James Uspensky. Hungarian analyst Gabor Szegö succeeded Blichfeldt and brought such mathematicians as George Pólya to Stanford. The author quotes at length from various memoirs and reminiscences and provides his own recollections from a long career at Stanford.

4683. Rudin, Walter. *The Way I Remember It*. (History of Mathematics, 12.). Providence: American Mathematical Society; London: London Mathematical Society, 1997. ix + 191 pp.

Autobiography and reminiscences of the Austrian-born, American analyst, Walter Rudin. Part I provides the biographical story, while Part II deals with Rudin's mathematical research.

4684. Rukeyser, Muriel. *Willard Gibbs*. Garden City: Doubleday, Doran & Company, Inc., 1942.

An account drawn from archival sources of the life of Yale mathematician, chemist, physicist, Josiah Willard Gibbs. Compare item 4700.

4685. Scanlon, Michael. "Who Were the American Postulate Theorists". *The Journal of Symbolic Logic* 56 (1991), 981–1002.

A study of those American mathematicians like Harvard's E. V. Huntington and Eliakim Hastings Moore and his students Oswald Veblen and Robert L. Moore at the University of Chicago who embraced the axiomatic approach inspired by David Hilbert's *Grundlagen der Geometrie* of 1899.

4686. Servos, John. "Mathematics and the Physical Sciences in America, 1880–1930". *Isis* 77 (1986), 611–629.

An analysis of the interrelations between mathematics and the physical sciences in the United States from 1880 to 1930. The author argues that the level and character of mathematical training in this period negatively affected the development of the physical sciences.

4687. Siegmund-Schultze, Reinhard. "'Scientific Control' in Mathematical Reviewing and German-U.S.-American Relations between the Two World Wars". *Historia Mathematica* 21 (1994), 306–329.

An analysis of mathematical reviewing between the two World Wars that examines the differences between the two German reviewing journals, the *Jahrbuch über die Fortschritte der Mathematik* and the *Zentralblatt für Mathematik* (f. 1931) and uncovers ideological and political dimensions of reviewing as a form of control over scientific communication and prestige.

4688. Siegmund-Schultze, Reinhard. "The Emancipation of Mathematical Research Publishing in the United States from German Dominance (1878–1945)". *Historia Mathematica* 24 (1997) 135–166.

This article documents the rise of mathematical publishing in the United States in the decades before World War II. The American mathematical community, emergent in the closing quarter of the nineteenth century, relied heavily on German publishing houses for the communication of its mathematical results. Drawing from archival sources, the author examines the policies of and relations between the American Mathematical Society and Springer-Verlag as well as the impact on American mathematics publishing of the Alien Property Custodian republication program, which aimed to make foreign (especially German) scientific books available during World War II. He argues that by the end of World War II, American mathematics publishing—having drawn heavily from its German model—had gained its independence.

4689. Simons, Lao G. "The Influence of French Mathematicians at the End of the Eighteenth Century upon the Teaching of Mathematics in American Colleges". *Isis* 15 (1931), 104–123.

The author explores the various influences that French mathematics had on mathematics in America during the first half of the nineteenth century. She cites such influences as the curricular reform, along the lines of the École polytechnique, after 1817 at the U. S. Military Academy at West Point, Nathaniel Bowditch's translation and commentary of Laplace's *Mécanique céleste*, and the adoption of French pedagogical approaches in a variety of college-level textbooks. Compare items 4673 and 4681.

4690. Smith, David Eugene, and Jekuthiel Ginsburg. *A History of Mathematics in America before 1900.* (The Carus Mathematical Monographs, no. 5.). Chicago: The Mathematical Association of America and Open

Court Publishing Company, 1934, x + 209 pp. New York: Arno Press, 1980.

Survey of American mathematics. Chapters 3 and 4 deal with the 19th century, providing basic information on major American figures, journals, societies, and universities, as well as foreign influences. Chapter 4 stresses the "little less than revolutionary" change which American mathematics underwent during the final quarter of the 19th century, attributing it to the educational reforms introduced by Daniel Coit Gilman and Charles W. Eliot, the founding of the American Mathematical Society, and German influence. Although written almost a half-century ago, this brief work is still occasionally cited as a starting-point for research, partly because it is replete with valuable materials such as lists of late 19th-century American doctoral dissertations in mathematics and subject-bibliographies of articles published by American mathematicians.

4691. Srinivasan, Bhama, and Judith Sally. *Emmy Noether in Bryn Mawr: Proceedings of a Symposium Sponsored by the Association for Women in Mathematics in Honor of Emmy Noether's 100th Birthday.* New York: Springer-Verlag, 1983. vii + 182 pp.

A collection of twelve papers, eight of which treat mathematical areas impacted by Noether's work and four of which are historical. The historical articles are: "Emmy Noether in Erlangen and Göttingen" by Emiliana P. Noether and E. Gottfried; "Emmy Noether in Bryn Mawr" by Grace S. Quinn et al.; "The Study of Linear Associative Algebra in the United States, 1870–1927" by Jeanne LaDuke; and "Emmy Noether: Historical Contexts" by Uta C. Merzbach. The book closes with a complete list of Emmy Noether's publications.

4692. Stigler, Stephen M., ed. *American Contributions to Mathematical Statistics in the Nineteenth Century.* New York: Arno Press, 1980. 2 vols.

A collection of thirty-six sources—mostly primary—documenting American activity in statistics during the nineteenth century. Papers reproduced are by Cleveland Abbe (1), R. J. Adcock (1), Robert Adrain (3), George B. Airy (1), Joseph Anderson (1), M. J. Babb (1), Julian Coolidge (1; compare item 4618), Erastus L. De Forest (4), Leo Goodman and William Kruskal (1), Charles Kummell (1), Mansfield Merriman (2), Simon Newcomb (5), Karl Pearson (1), Benjamin Peirce (1), Benjamin Peirce and Charles Schott (1), Charles S. Peirce (3), Charles S. Peirce and J. Jastrow (1), Stephen Stigler (2), Edward Wigglesworth (1), Edwin B. Wilson and Margaret M. Hilfery (1), Joseph Winlock (1), Hugh Wolfenden (1), Robert S. Woodward (1), and T. W. Wright (1).

4693. Stigler, Stephen M. “Mathematical Statistics in the Early States”. *Annals of Statistics* 6 (1978), 239–265.

An historical overview of the history of mathematical statistics in nineteenth-century America. The author examines the roles and the work of such figures as Robert Adrain (1775–1843), Benjamin Peirce (1809–1880) and Charles S. Peirce (1839–1914), Simon Newcomb (1835–1909), and Erastus L. De Forest(1834–1888). Among the topics explored by these Americans were outlier rejection procedures, the randomized design of experiments, the fitting of gamma distributions by the method of moments, and kernel estimation of density functions. The author argues that while advances were almost nonexistent prior to 1850, activity picked up greatly between 1850 and 1885.

4694. Struik, Dirk. “The MIT Department of Mathematics during its First Seventy-Five Years: Some Recollections”. In *A Century of Mathematics in America—Part III.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 163–178.

A look at the history of the Department of Mathematics at the Massachusetts Institute of Technology from its beginnings as a service department under John Daniel Runkle through its emergence as a major research department by the outbreak of World War II. Among those who figure prominently in the story are Harry W. Tyler, Frederick S. Woods, Clarence L. E. Moore, Philip Franklin, Norman Levinson, Henry B. Phillips, Jesse Douglas, and Eric Reissner.

4695. Tarwater, Dalton, ed. *The Bicentennial Tribute to American Mathematics: 1776–1976.* Washington, D.C.: The Mathematical Association of America, 1977.

Five of the essays in this volume concern twentieth-century mathematics: Garrett Birkhoff describes leaders in American mathematics from 1891 to 1940. J. H. Ewing and five co-authors depict the changing status of ten leading problems from as many mathematical subdisciplines. M. S. Rees writes of her years in the Office of Naval Research. R. W. Hamming supplies a history of computing in the United States, while P. D. Lax deals with external influences on American mathematics since 1940.

4696. Ulam, S. M., et al. “John von Neumann, 1903–1957”. *Bulletin of the American Mathematical Society* 64 (May 1958), 1–129 (supplement [=No. 3, Part 2]).

This supplement was devoted exclusively to von Neumann’s life and work. Ulam supplied a brief biography and discussed aspects of von Neumann’s wide-ranging researches. The remainder of the supplement consists of essays on his contributions to lattice theory (Garrett Birkhoff), operator theory (F. J. Murray and R. V. Kadison), measures and ergodic theory (P. R. Halmos), quantum theory (L. Van Hove), game theory and mathematical economics (H. W. Kuhn and A. W. Tucker), and finally to automata theory (C. E. Shannon). See also Halmos's anecdotal biography in the *American Mathematical Monthly* 80 (1973), 382–394.

4697. Veblen, Oswald. "George David Birkhoff (1884-1944)". *Yearbook of the American Philosophical Society* (1946), 279–285.

A biographical article on the Harvard mathematician, George David Birkhoff.

4698. Veblen, Oswald. "Henry Burchard Fine—In Memorium". *Bulletin of the American Mathematical Society 35 (1929), 726–730.*

A biographical article of Henry Burchard Fine, Princeton mathematician and initial driving force behind Princeton's move from an undergraduate to a major research department.

4699. Walsh, Joseph L. "William Fogg Osgood". In *A Century of Mathematics in America—Part II.* Edited by Peter Duren, et al. Providence: American Mathematical Society, 1989, 79–85.

A biographical article on William Fogg Osgood from the papers of Joseph L. Walsh housed in the Harvard University Archives and published for the first time in 1989. Together with Maxime Bôcher, Osgood transformed the Harvard Mathematics Department into a major research department beginning in the 1890s.

4700. Wheeler, Lynde Phelps. *Josiah Willard Gibbs: The History of a Great Mind.* New Haven: Yale University Press, 1952.

A non-technical biography of the Yale mathematician, chemist, physicist, Josiah Willard Gibbs. Compare item 4684.

4701. White, Henry Seely "Autobiographical Memoir of Henry Seely White (1861-1943)". *Biographical Memoirs of the National Academy of Sciences* 25 (1944), 16–33.

An autobiography (with photograph and bibliography) of one of the early leaders of the emergent American mathematical research community. It provides an interesting insight into the training of American mathematicians during the closing quarter of the nineteenth century.

4702. Wiener, Norbert. *I Am a Mathematician.* New York: Doubleday, 1956.

An autobiography of his mathematical career, especially concerning quantum mechanics, the atomic bomb, and cybernetics. Includes reminiscences about many European and American mathematicians. For Wiener's youth and adolescence, see his earlier autobiographical volume, *Ex-Prodigy: My Childhood and Youth* (New York: Simon and Schuster, 1953).

4703. Wilder, Raymond L. "The Mathematical Work of R. L. Moore: Its Background, Nature, and Influence". *Archive for History of Exact Sciences* 26 (1982), 73–97.

A study of the work of American topologist, Robert L. Moore. The author opens with a biographical account of Moore, moves to a discussion of Moore's work on geometry, analysis, point set topology, continuous curves, the structure of continua, and closes with an analysis of the impact of Moore's ideas on mathematics. This article was reprinted in item 4623 Part III, pp. 265–291.

4704. Woodward, Robert S. "The Century's Progress in Applied Mathematics". *Bulletin of the American Mathematical Society* 6 (1900), 133–163.

Presidential address of the fifth President of the American Mathematical Society, Robert Woodward. The article surveys nineteenth-century developments in applied mathematics, which included for Woodward analytical mechanics, geodesy, dynamical astronomy, observational astronomy, the theory of elasticity, and hydromechanics. North Americans such as William Ferrel, George William Hill, Simon Newcomb, and Ernest W. Brown figure in the account.

Mexico

Research journals

4705. *Anales de la Sociedad Mexicana de Historia de la Ciencia y la Tecnología*. México: Sociedad Mexicana de Historia de la Ciencia y de la Tecnología. Vol. I (1969), Vol. II (1970), Vol. III (1972), Vol. IV (1974), Vol. V (1979).

Research journal of the original "Sociedad Mexicana de Historia de la Ciencia y la Tecnología". Most articles are concerned with the history of the physical and biological sciences and technology in Mexico.

4706. *Mathesis*. México: Departamento de Matemáticas, Facultad de Ciencias, Universidad Nacional Autónoma de México. 1985 -.

Research journal devoted to the history and philosophy of mathematical ideas, from the origins of man. *Mathesis* publishes secondary sources as well as original or primary documents. *Mathesis*'s official languages include Spanish and English.

4707. *Quipu*. México: Sociedad Latinoamericana de Historia de la Ciencia y la Tecnología. 1984 -

Research journal devoted to the history of science and technology in Latin America. It publishes articles in Spanish, French, English and Portuguese.

Proceedings of Specialized Congresses and Meetings

4708. *Memorias del Primer Coloquio Mexicano de Historia de la Ciencia (México, D. F. September 2-7, 1963.* Vol.I, 406 pp.; Vol.II, 434 pp.

Enrique Belt'an organized the first congress devoted to the study of the history of Mexican science. The thematic of the congress covers precolumbian, colonial and independent times.

4709. *Memoria del Congreso Científico Mexicano. IV Centenary of the Mexican National University (1551-1951).* México: Universidad Nacional Autónoma de México, 1953.

The National University of Mexico organized this congress to celebrate its first 500 years. The first five volumes of the proceedings (Vol. I, 1955, 522 pp.; Vol. II, 1954, 560 pp.; Vol. III, 1954, 430 pp.; Vol. IV, 1954, 321 pp. and Vol. V, 1954, 567 pp.) are devoted to the exact sciences. Some of the articles present survey discussions of the mathematical original research developed in Mexico.

Primary Sources

4710. Trabulse, Elías. *Historia de la Ciencia en México. Estudio y Textos.* México: Fondo de Cultura Económica & Conacyt, Vol. I (1983): Century XVI, 461 pp.; Vol. II (1984): Century XVII, 298 pp.; Vol. III (1985): Century XVIII, 513 pp.; Vol. IV (1985), Century XIX, 426 pp.; Vol. V (1989): Appendixes and indexes 591 pp.

Extraordinary effort to compile extracts of original scientific texts from the XVI to the XIX centuries.

Secondary Sources

4711. Beuchot, Mauricio. *Estudios de Historia y de Filosofía en el México Colonial.* México: Universidad Nacional Autónoma de México, 1991, 216 pp.

Mainly concerned with the study of the history of philosophy during the Colonial period.

4712. Closs, Michael, ed. *Native American Mathematics.* Austin: University of Texas Press, 1986. 431 pp.

This source contains contributions discussing mathematical ideas of diverse native American groups (e.g., Amazon, Inca, Aztec, Maya, etc.).

4713. Gárces, Guillermo. *Pensamiento Matemático y astronómico en el México precolombino.* 2nd ed., México: Instituto Politécnico Nacional, 1990, 360 pp.

A first part (75 pp.) contains a discussion of the evolution of the concept of number in different cultures (e.g., Egyptian, Greek, Hindu, etc.); a second part (77-177 pp.) discusses the origins of mathematical and astronomical disciplines within the Mayan culture; and, a third part

(179-360 pp.) studies the influence of the Mayan developments within other mesoamerican cultures.

4714. Gortari, Eli de. *La ciencia en la historia de México.* México: Fondo de Cultura Económica, 1963, 461 pp.

Impressive effort, produced under a Marxist perspective, to discuss the role of science (and technology) in the development of Mexican history. Although now outdated, this book enumerates an amazing number of primary and secondary sources.

4715. Leonard, Irving A. *Don Carlos de Sigüenza y Góngora. Un sabio mexicano del siglo XVII.* Translated from English by Juan José Utrilla. México: Fondo de Cultura Económica, 1984, 316 pp.

This is an intellectual biography of this Mexican scholar, astronomer and mathematician.

4716. Moreno, Roberto. *Ensayos de Historia de la Ciencia y la Tecnología en México.* México: Universidad Nacional Autónoma de México, 1986. 173 pp.

This volume contains several articles most of them concerned with the development of the biological sciences published (in several journals and magazines) by the late Roberto Moreno.

4717. Prieto, Sotero. *Historia de las Matemáticas.* México: IMC Ediciones, 1991, 145 pp. + supp.

Facsimile notes of a course delivered on the history mathematics at the Mexican National University in 1940 and 1941. Although, Prieto's original calligraphy is legible, the notes are extremely sketchy and mainly list the facts that were discussed during the course. But there is no discussion of the selection of the topics or the sources used.

4718. Trabulse, Elías. *Ciencia y religión en el siglo XVII.* México: El Colegio de México, 1974, 286 pp.

Trabulse, following explicitly a Kuhnian model, reconstructs the debate between Carlos de Sigüenza and Frier Kino concerning the comet of 1640.

RUSSIA AND THE SOVIET UNION

4719. Demidov, S. S. "Der Philosophische Kontext der Herausbildung der Moskauer Funktionentheoretischen Schule". *Zeitschrift für Geschichte der Naturwissenschaft, Technik, und Medizin* 25 (2) (1988), 25–31.

A discussion of the foundations of one of the century's prominent mathematical schools.

4720. Ermolaeva, N. S. “The Early Years of Russian Mathematical Emigration” In Russian. *Voprosy Istorii Estestvoznaniya i Tekhniki* (2) (1992), 50–61.

The early years referred to are the last two decades of tsarist Russia (1900–1920). This article also contains biographical information on many of the people involved in the emigration.

4721. Forsythe, G. E. *Bibliography of Russian Mathematics Books*. New York: Chelsea, 1956.

Provides a general survey of books in Russian (with English translations given for titles) in all areas of mathematics. The subject index guides readers to sources for history, including bibliographic materials and collected papers.

4722. Gnedenko, B. V. “The Development of Mathematics in the USSR in the Last 60 Years”. In Russian. *Matematika v Shkole* 5 (1977), 12–19.

The author gives a broad general survey of a vast amount of mathematics developed in the Soviet Union during its first 60 years, emphasizing the connection between theory and practice.

4723. Phillips, Esther R. “Nicolai Nicolaevich Luzin and the Moscow School of the Theory of Functions”. *Historia Mathematica* 5 (1978), 275–305.

Luzin’s role in the emergence of the Moscow school straddled the Russian Revolution; his interests in set theory and analysis are shown to have been decisive for the careers of Alexandrov, Khinchin, Souslin, and Kolmogorov, among others.

4724. Tobies, R. “Contact between Soviet and German Mathematicians: P. S. Aleksandrov and German Mathematics. In Russian. *Istoriko-Matematicheskie Issledovaniya* No. 32–33 (1990), 417–430. ”

This paper contains a description of the way in which Soviet and German mathematicians collaborated and the special role played in that collaboration by Aleksandrov.

4725. Yushkevich, A. P. “The N. N. Luzin Affair”. In Russian. *Vestnik Akademiia Nauk SSSR* no.4 (1989), 102–113.

A detailed description of one of the more prominent cases of government intrusion to control the scientific community in the Soviet Union during the Stalin era. It makes an interesting counterpoint with the fate of mathematicians at the hands of the Nazis.

4726. Korneĭchuk, N. P. “S. M. Nikol’skiĭ and the Soviet School of Approximation Theory”. *Trudy Matematicheskogo Instituta imeni V. A. Steklova* 180 (1987), 3–12.

A survey of the achievements of one of the major schools of approximation theory, written by one of its most distinguished members and dedicated to its acknowledged leader.

WOMEN IN MATHEMATICS

Since the early 1980s the number of works about women in mathematics has grown significantly. With some notable exceptions, much of the material in reference works occurs in those that deal more broadly with women in science. Also, newsletters, especially the *Association for Women in Mathematics Newsletter*, and unrefereed conference proceedings contain many items such as reprints, obituaries, and short articles that are of interest but cannot be detailed individually. In addition to the historical studies dealing with particular themes or communities that are listed, information about other works may be found on websites, only a few of which will be noted.

General Reference Works

In addition to the published works listed below, one can find a bibliography on women in mathematics at the website maintained by Marie Vitulli, Women in Math Project (http://darkwing.uoregon.edu/~wmnmath/).

4727. *Association for Women in Mathematics Newsletter*. University of Maryland, College Park: Association for Women in Mathematics, 1971–.

Contains many biographical articles on women mathematicians and other articles on issues that concern women and mathematics. Historical articles appear starting in 1976; many are reprinted from other sources. Not indexed. Issued bimonthly since 1979.

4728. Bailey, Martha J. *American Women in Science: A Biographical Dictionary*. Santa Barbara, Calif.: ABC-CLIO, 1994, xxi + 463 pp.

Includes information on education and employment, and brief sketches of some aspects of the lives, of twenty-four American women in mathematics who began their careers prior to 1950. Information is usually taken from standard reference works.

4729. *Directory of Women Mathematicians: 1973–1974*. Providence, R.I.: American Mathematical Society, 1973, 49 pp. With annual supplements through 1977–1978.

Each listing contains information supplied by the individual on professional position, Ph.D. degree date and institution, thesis title and supervisor, fields of interest, and a partial bibliography. Later directories appear under the title *Directory of Women in the Mathematical Sciences*. The first of these appeared in 1981 and was published by the Joint Committee on Women in Mathematics; the second appeared in 1987 and was published by the Association for Women in Mathematics. Both include all of the above mentioned information except thesis title and supervisor. In 1995 the Association for Women in Mathematics published

1995–1996 Directory of Women Mathematicians. This directory includes no bibliographic or degree information; it lists 2,641 individuals.

4730. Grinstein, Louise S., and Paul J. Campbell, eds. *Women of Mathematics: A Biobibliographic Sourcebook*. Westport, Conn.: Greenwood Press, 1987, xxii + 292 pp.

Forty-three essays on individual women mathematicians. Each essay includes a biography, a description of the person's work, a publication list, and references to works about her. Both famous and relatively unknown women are included. Begins with "Foreword" by Alice Schafer (pp. ix–xii), "Preface" by Paul J. Campbell and Louise S. Grinstein (pp. xiii–xv), and "Introduction" by Jeanne LaDuke (pp. xvii–xx). Individual articles are: "Maria Gaetana Agnesi (1718–1799)" by Hubert Kennedy (pp. 1–5), "Nina Karlovna Bari (1901–1961)" by Joan Spetich and Douglas E. Cameron (pp. 6–12), "Ruth Aaronson Bari (1917–)" by Florence D. Fasanelli (pp. 13–16), "Dorothy Lewis Bernstein (1914–)" by Ann Moskol (pp. 17–20), "Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet (1706–1749)" by Garry J. Tee (pp. 21–25), "Gertrude Mary Cox (1900–1978)" by Maryjo Nichols (pp. 26–29), "Käte Fenchel (1905–1983)" by Else Høyrup (pp. 30–32), "Irmgard Flügge-Lotz (1903–1974)" by John R. Spreiter and Wilhelm Flügge (pp. 33–40), "Hilda Geiringer von Mises (1893–1973)" by Joan L. Richards (pp. 41–46), "Sophie Germain (1776–1831)" by Mary W. Gray (pp. 47–56), "Evelyn Boyd Granville (1924–)" by Patricia Clark Kenschaft (pp. 57–61), "Ellen Amanda Hayes (1851–1930)" by Ann Moskol (pp. 62–66), "Grace Brewster Murray Hopper (1906–)" by Amy C. King with Tina Schalch (pp. 67–73), "Hypatia (370?–415)" by Ian Mueller (pp. 74–79), "Sof′ja Aleksandrovna Janovskaja (1896–1966)" by Irving H. Anellis (pp. 80–85), "Carol Karp (1926–1972)" by Judy Green (pp. 86–91), "Claribel Kendall (1889–1965)" by Ruth Rebekka Struik (pp. 92–94), "Pelageya Yakovlevna Polubarinova-Kochina (1899–)" by George W. Phillips (pp. 95–102), "Sofia Vasilevna Kovalevskaia (1850–1891)" by Ann Hibner Koblitz (pp. 103–113), "Edna Ernestine Kramer Lassar (1902–1984)" by Sally Irene Lipsey (pp. 114–120), "Christine Ladd-Franklin (1847–1930)" by Judy Green (pp. 121–128), "Elizaveta Fedorovna Litvinova (1845–1919?)" by Ann Hibner Koblitz (pp. 129–134), "Augusta Ada Lovelace (1815–1852)" by Karen D. Rappaport (pp. 135–139), "Sheila Scott Macintyre (1910–1960)" by Florence D. Fasanelli (pp. 140–143), "Ada Isabel Maddison (1869–1950)" by Betsey S. Whitman (pp. 144–146), "Helen Abbot Merrill (1864–1949)" by Claudia Henrion (pp. 147–151), "Cathleen Synge Morawetz (1923–)" by James D. Patterson (pp. 152–155), "Hanna Neumann (1914–1971)" by M. F. Newman (pp. 156–160), "Mary Frances Winston Newson (1869–1959)" by Betsey S. Whitman (pp. 161–164), "Emmy Noether (1882–1935)" by

Gottfried E. Noether (pp. 165–170), “Rózsa Péter (1905–1977)” by Hajnal Andréka (pp. 171–174), “Mina Rees (1902–)” by Phyllis Fox (pp. 175–181), “Julia Bowman Robinson (1919–1985)” by Constance Reid with Raphael M. Robinson (pp. 182–189), “Mary Ellen Rudin (1924–)” by Rosemary McCroskey Karr, Jaleh Rezaie, and Joel E. Wilson (pp. 190–192), “Charlotte Angas Scott (1858–1931)” by Patricia Clark Kenschaft (pp. 193–203), “Mary Emily Sinclair (1878–1955)” by Laurel G. Sherman (pp. 204–207), “Mary Fairfax Greig Somerville (1780–1872)” by Elizabeth Chambers Patterson (pp. 208–216), “Pauline Sperry (1885–1967)” by Florence D. Fasanelli (pp. 217–219), “Alicia Boole Stott (1860–1940)” by H. S. M. Coxeter (pp. 220–224), “Olga Taussky-Todd (1906–)” by Edith H. Luchins (pp. 225–235), “Mary Catherine Bishop Weiss (1930–1966)” by Guido Weiss (pp. 236–240), “Anna Johnson Pell Wheeler (1883–1966)” by Louise S. Grinstein and Paul J. Campbell (pp. 241–246), and “Grace Chisholm Young (1868–1944)” by Sylvia M. Wiegand (pp. 247–254). See reviews by Joella G. Yoder in *Historia Mathematica* 16 (1989), 289–291 and Robin E. Rider in *Science* 238 (20 November 1987), 1153–1154. The articles on Charlotte Scott, Anna Pell Wheeler, and Julia Robinson were reprinted in *A Century of Mathematics in America, Part III* item 4623.

4731. Høyrup, Else. *Women of Science, Technology, and Medicine: A Bibliography.* Roskilde, Denmark: Roskilde University Library, 1987, viii + 132 pp.

Over 100 pages of entries arranged alphabetically by subject. Includes a short section of more general works on women in mathematics (pp. 108–110).

4732. Morrow, Charlene, and Teri Perl, eds. *Notable Women in Mathematics: A Biographical Dictionary.* Westport, Conn.: Greenwood Press, 1998, xv + 302 pp.

Fifty-nine biographical essays on individual women mathematicians intended for secondary school students and the general public. Descriptions of mathematical research are given in non-technical terms. All but thirteen of the women profiled have worked in the United States; almost half were under sixty at the time of publication. The individual entries are: “Maria Gaetana Agnesi” (pp. 1–6), “Andrea Bertozzi” (pp. 6–11), “Lenore Blum” (pp. 11–16), “Sylvia Bozeman” (pp. 17–21), “Marjorie Lee Browne” (pp. 21–25), “Leone Burton” (pp. 25–29), “Fan King Chung” (pp. 29–34), “Ingrid Daubeschies” (pp. 34–38), “Emilie de Breteuil du Chatelet” (pp. 38–43), “Etta Zuber Falconer” (pp. 43–47), “Joan Feigenbaum” (pp. 47–51), “Elizabeth Fennema” (pp. 51–56), “Herta Taussig Freitag” (pp. 56–61), “Sophie Germain” (pp. 62–66), “Evelyn Boyd Granville” (pp. 66–71), “Mary Gray” (pp. 71–76), "Gloria Conyers Hewitt" (pp. 76–79), "Grace Brewster Murray Hopper" (pp. 80–85), "Rhonda Hughes" (pp. 85–89), "Joan Hutchinson" (pp. 90–93), "Hypatia" (pp. 94–97), "Nancy Kopell" (pp. 98–102), "Sofya Korvin-Krukovskaya Kovalevskaya" (pp. 102–107), "Christine Ladd-Franklin" (pp. 107–113), "Anneli Lax" (pp. 113–118), "Gilah Chaya Vanderhoek Leder" (pp. 118–123), "Emma Trotskaya Lehmer" (pp. 123-128), "Ada Augusta Byron Lovelace" (pp. 128–133), "Vivienne Malone-Mayes" (pp. 133–137), "Dusa Waddington McDuff" (pp. 137–142), "Marie-Louise Michelsohn" (pp. 142–147), "Cathleen Synge Morawetz" (pp. 147–152), "Emmy Noether" (pp. 152–157), "Karen Parshall" (pp. 157–160), "Bernadette Perrin-Riou" (pp. 161–164), "Harriet Pollatsek" (pp. 164–169), "Cheryl Praeger" (pp. 169–173), "Mina Spiegel Rees" (pp. 174–180), "Ida Rhodes" (pp. 180–185), "Julia Bowman Robinson" (pp. 185–190), "Judith Roitman" (pp. 190–195), "Mary Ellen Rudin" (pp. 195–200), "Mary Beth Ruskai" (pp. 200–204), "Cora Sadosky" (pp. 204–209), "Alice Turner Schafer" (pp. 209–214), "Doris Wood Schattschneider" (pp. 214–219), "Charlotte Angas Scott" (pp. 219–224), "Marjorie Wikler Senechal" (pp. 225–229), "Lesley Milman Sibner" (pp. 229–233), "Mary Fairfax Grieg Somerville" (pp. 233–238), "Pauline Sperry" (pp. 238–242), "Alicia Boole Stott" (pp. 242–246), "Olga Taussky-Todd" (pp. 246–252), "Jean Taylor" (pp. 252–257), "Chuu-Lian Terng" (pp. 257–261), "Karen Uhlenbeck " (pp. 261–266), "Marion Walter" (pp. 267–272), "Sylvia Young Wiegand" (pp. 272–277), and "Grace Chisholm Young" (pp. 277–282).

4733. Ogilvie, Marilyn Bailey. *Women in Science: Antiquity Through the Nineteenth Century: A Biographical Dictionary with Annotated Bibliography.* Cambridge, Mass.: MIT Press, 1986, xiv + 254 pp.

There are three main sections: an introductory essay (pp. 2–21), bibliographical accounts arranged alphabetically by subject (pp. 22–178), and a briefly annotated bibliography (pp. 189–239). All subjects are western and were born before 1885.

4734. Ogilvie, Marilyn Bailey, with Kerry Lynne Meek. *Women and Science: An Annotated Bibliography.* New York: Garland Publishing Inc., 1996, x + 556 pp.

Entries are arranged alphabetically by author and given unique record numbers. Keywords are assigned according to six categories, including field, with over 150 items listed in the field index for mathematics.

4735. Rebière, A. *Les femmes dans la science.* 2nd ed. Paris: Libraire Nony et Cie, 1897. 1st ed. 1894, with subtitle, *Conférence faite au Cercle Saint-Simon le 24 février 1894.*

Probably the first extensive collection of biographies of women in science. First edition is an 87-page brochure. Second edition includes 285 pages of biography and two appendices: "Si la femme est capable de science—opinions diverses" and "Menus propos sur les femmes et les sciences—notules diverses." Includes substantial entries on Agnesi, du Châtelet, Germain, Hypatia, Kovalevskaya, and Somerville, each with bibliographies and references. Also contains short entries on other women mathematicians and on women who influenced male mathematicians.

4736. Siegel, Patricia Joan, and Kay Thomas Finley. *Women in the Scientific Search: An American Bio-bibliography, 1724–1979.* Metuchen, N.J.: The Scarecrow Press Inc., 1985, xviii + 399 pp.

Biographical entries with individual bibliographies are arranged by field. Includes brief entries for nineteen mathematicians based on secondary sources, obituary notices, and occasionally on reports from college archivists.

4737. Valentin, G. "Die Frauen in den exakten Wissenschaften". *Bibliotheca Mathematica* 9 (1895), 65–76.

Bibliography of works by seventy-one women in mathematics, astronomy, and physics. In some cases includes biographical references. Corrections and additions appear in G. Eneström, "Note bibliographique sur les femmes dans les sciences exacte", *Bibliotheca Mathematica* 10 (1896), 73–76.

Thematic Studies

These works focus on themes or issues that pertain to more than one person. For works about individual women mathematicians, see the following section.

4738. Anand, Kailash K. "Canadian Women Mathematicians from the Early Nineteenth Century to 1960–A More Comprehensive Study". *Canadian Mathematical Society Notes* 21 no. 5 (1989), 31–42.

Brief biographies of eleven (of at least fifteen) Canadian women with Ph.D.'s in mathematics earned by 1960. The sketches are uneven in quality and quantity of detail.

4739. Archibald, Raymond Clare. "Women as Mathematicians and Astronomers". *American Mathematical Monthly* 25 (1918), 136–139.

The first of a large number of articles featuring short biographies of women mathematicians. Early biographical and bibliographical references.

4740. Eells, Walter Crosby. "American Doctoral Dissertations on Mathematics and Astronomy Written by Women in the Nineteenth Century". *The Mathematics Teacher* 50 (1957), 374–376.

Lists eleven women (plus Christine Ladd-Franklin who earned a degree in 1882 that was not awarded until 1926), their dates, degree institution, dissertation title, date, and publication source. Missing from this list is Agnes Sime Baxter, Cornell, 1895.

4741. *The Emmy Noether Lectures: Profiles of Women in Mathematics.* University of Maryland, College Park: Association for Women in Mathematics, 1994, 20 pp.

The first edition in 1988, *The Emmy Noether Lecturers*, includes brief sketches of the lives and work of the women who delivered the first nine Emmy Noether lectures (1980–1988). The 1994 edition includes profiles of the 1980–1994 lecturers. Sketches are available from AWM for subsequent lecturers.

4742. Farquhar, Diane, and Lynn Mary-Rose. *Women Sum It Up: Biographical Sketches of Women Mathematicians.* Christchurch, New Zealand: Hazard Press, 1989, 95 pp.

Contains two sections. One on European and American women has twenty brief biographies generally based on secondary sources, with few or no references. Eight women are profiled in a section on Australian and New Zealand women.

4743. Fenster, Della Dumbaugh, and Karen Hunger Parshall. "Women in the American Mathematical Research Community: 1891–1906". In *The History of Modern Mathematics, Vol. III.* Edited by Eberhard Knobloch and David E. Rowe. Boston, Mass.: Academic Press, Inc., 1994, 229–261.

Gives a brief introduction to the higher education of women in the U.S. and analyzes data in early issues of the *Bulletin of the New York Mathematical Society* (later *Bulletin of the American Mathematical Society*) to identify seventy-one women who participated in activities of the society by giving talks, publishing papers, contributing service, or attending meetings. Contains extensive endnotes. Companion piece to "A Profile of the American Mathematical Research Community: 1891–1906", item 4626, by the same authors in the same volume.

4744. Field, J. B. F., F. E. Speed, T. P. Speed, and J. M. Williams. "Biometrics in the CSIR: 1930–1940". *The Australian Journal of Statistics* 30 (B) (1988), 54–76.

Biographies of three women statisticians who worked for the Council for Scientific and Industrial Research (CSIR). Also lists their publications during the 1930s.

4745. Green, Judy, and Jeanne LaDuke. "Women in the American Mathematical Community: the Pre-1940 Ph.D.'s". *The Mathematical Intelligencer* 9 no. 1 (1987), 11–23.

Describes the education and career patterns of the 229 American women who received Ph.D.'s in mathematics before 1940. For the participation of women in American mathematical institutions see

"Women in American Mathematics: A Century of Contributions" by Judy Green and Jeanne LaDuke in *A Century of Mathematics in America, Part II*, item 4623, 379–398.

4746. Green, Judy, and Jeanne LaDuke. "Contributors to American Mathematics: An Overview and Selection". In *Women of Science: Righting the Record*. Edited by G. Kass-Simon and Patricia Farnes. Bloomington: Indiana University Press, 1990, 117–146. First Midland Book Edition, 1993.

Describes "some aspects of the lives and work of nine women, each of whom contributed significantly to mathematics or was in some way a pioneer in the American mathematical community" before World War II.

4747. Henrion, Claudia. *Women in Mathematics: The Addition of Difference*. Bloomington: Indiana University Press, 1997, xxxi + 293 pp.

Based on interviews conducted between 1988 and 1993 with eleven American women mathematicians. The personal experiences of nine of the eleven are interpreted in order to "challenge . . . myth[s]" about mathematicians. Introduction gives short historical background focusing on four frequently profiled women mathematicians. See review by Ann Hibner Koblitz in *Notices of the American Mathematical Society* 45 (1998), 606–609.

4748. *IEEE Annals of the History of Computing*. 18 no. 3, (1996), 3–55.

Special issue on women in computing edited by Campbell, Betty. Includes four historical articles: "Ada Byron, Lady Lovelace, An Analyst and Metaphysician" by Betty Alexandra Toole (pp. 4–12), "The Women of ENIAC" by W. Barkley Fritz (pp. 13–28), "Women's Contributions to Early Computing at the National Bureau of Standards" by Denise W. Gürer (pp. 29–35), and "Women in Computing: Historical Roles, the Perpetual Glass Ceiling, and Current Opportunities" by Amita Goyal (pp. 36–42).

4749. Katok, Anatole, and Svetlana Katok. "Women in Soviet Mathematics". *Notices of the American Mathematical Society* 40 (1993), 108–116.

Gives a "brief outline of the general situation of women in the Soviet Union from its beginnings." Discusses the work of some "outstanding women mathematicians" born in the first quarter of the twentieth century.

4750. Kenschaft, Patricia C. "Black Women in Mathematics in the United States". *American Mathematical Monthly* 88 (1981), 592–604.

Short descriptions of twenty-one African-American women who received Ph.D.'s in mathematics by 1980. Many are based on interviews or correspondence. Also appears in *Journal of African Civilizations* 4 no. 1 (1982), 63–83, with a postscript including descriptions of three more women.

4751. Klens, Ulrike. *Mathematikerinnen im 18. Jahrhundert: Maria Gaetana Agnesi, Gabrielle-Emilie Du Châtelet, Sophie Germain: Fallstudien zur Wechselwirkung von Wissenschaft und Philosophie im Zeitalter der Aufklärung.* Pfaffenweiler: Centaurus-Verlagsgesellschaft, 1994, 391 pp.

Examines the work, and its reception, of Agnesi, du Châtelet, and Germain, particularly in the larger context of Enlightenment science and philosophy. Contains bibliography of works by and about each.

4752. Kramer, Edna E. "Six More Female Mathematicians". *Scripta Mathematica* 23 (1957), 83–95.

Written to show that Julian L. Coolidge's list of "Six Female Mathematicians" (Hypatia, Agnesi, du Châtelet, Somerville, Germain, and Kovalevskaya) in *Scripta Mathematica* 17 (1951), 20–31, can be greatly expanded if the period subsequent to 1900 is considered. Includes short biographies, based primarily on interviews with the mathematicians themselves, of a sample of six twentieth-century Europeans. A revised version appears in Edna E. Kramer, *The Nature and Growth of Modern Mathematics* (New York: Hawthorn Books Inc., 1970), 703–714.

4753. Loria, Gino. "Les femmes mathématiciennes". *Revue Scientifique* Series 4, 20 (1903), 385–392.

Example of a mathematician's attempt to discredit the contributions of women mathematicians. Criticized by J. Joteyko in "À propos des femmes mathématiciennes", *Revue Scientifique* Series 5, 1 (1904), 12–15. Reply by Loria in "Encore les femmes mathématiciennes", *Revue Scientifique* Series 5, 1 (1904), 338–340.

4754. Mozans, H. J. [John A. Zahm, C.S.C.] *Woman in Science*. 1913. Reprinted Cambridge, Mass.: The MIT Press, 1974, xvii + 452 pp. Reissued Notre Dame, Ind.: University of Notre Dame Press, 1991, xxvi + 452 pp.

Contains a 21-page chapter on women in mathematics featuring the same women as those featured by Rebière, item 4735. Naive historical judgments on mathematics. Several biographical references. The 1974 work contains an added introduction; the 1991 reissue includes a new introduction and preface.

4755. Osen, Lynn M. *Women in Mathematics*. Cambridge, Mass.: The MIT Press, 1974, xii + 185 pp.

Biographies of eight women mathematicians from Hypatia through Noether. Contains brief comments on contributions by contemporary women mathematicians and references. Not written for mathematicians. See review by Mary E. Williams in *Historia Mathematica* 2 (1975), 348.

4756. Pereira da Silva, Clovis. "A Mulher na Comunidade Matemática Brasileira, de 1879 a 1979". *Quipu: Revista Latinoamericana de Historia de las Ciencias y la Technologia* 5 (1988), 277–289.

Includes a brief discussion of the growth of advanced mathematical education in Brazil, a section on North American and European women in mathematics–material available elsewhere–and a survey of Brazilian women obtaining doctorates in mathematics, the first in 1950.

4757. Perl, Teri. "The *Ladies' Diary* or *Woman's Almanack*, 1704–1841". *Historia Mathematica* 6 (1979), 36–53.

Analyzes patterns of participation by female contributors to a popular women's magazine that was largely devoted to mathematical problems and puzzles. An earlier version appears as "The Ladies' Diary…Circa 1700", *The Mathematics Teacher* 70 (1977), 354–358.

4758. Skowron, Andrzej, ed. *Logic, Algebra and Computer Science: Helena Rasiowa and Cecylia Rauszer, in Memoriam.* Łódź: University of Łódź. Department of Logic, 1996, i–ii and 119–208.

Special issue of *University of Łódź. Department of Logic. Bulletin of the Section of Logic.* 25 no. 3–4 (1996). Includes articles on the lives, work, and publications of the Polish logicians Helena Rasiowa and Cecylia Rauszer.

4759. Stinnett, Sandra, et al. "Women in Statistics: Sesquicentennial Activities". *The American Statistician* 44 (1990), 74–80.

Includes "selected vignettes of the women featured in the display on women in statistics" at the 1989 Joint Statistical Meetings. These nine include the six women who had been presidents of the American Statistical Association.

4760. Tobies, Renate. "Zum Beginn des mathematischen Frauenstudiums in Preussen". *NTM Schriftenreihe für Geschichte der Naturwissenschaften Technik und Medizin* 28 no. 2 (1991/92), 151–172.

Uses archival sources to examine the issues surrounding the admission of women to Prussian universities with a focus on the supportive role of Felix Klein. An appendix contains reproductions of letters from the earliest women admitted, a list of report topics of women in Klein's seminars, and correspondence concerning the early denial of *Habilitation* for Emmy Noether at Göttingen.

4761. Tobies, Renate, ed. *Aller Männerkultur zum Trotz: Frauen in Mathematik und Naturwissenschaften.* Frankfurt: Campus Verlag, 1997, 288 pp.

A valuable volume that includes five articles specifically related to mathematics: "Einführung: Einflußfaktoren auf die Karriere von Frauen in Mathematik und Naturwissenschaften" by Renate Tobies (17–67), "Zwei erste Promotionen: Die Mathematikerin Sofja Kowalewskaja und die Chemikerin Julia Lermontowa" by Cordula Tollmien (83–129), "Mathematikerinnen und ihre Doktorväter" by Renate Tobies (131–158), "Die Schwestern Johanna und Gertrud Wiegandt promovieren in Mathematik: Einflußfaktoren auf ihre Karriere" by Waltraud Voss (159–179), and "Ruth Moufang (1905–1977): Eine Mathematikerin Zwischen Industrie und Universität" by Irene Pieper-Seier (181–202). Articles are detailed, make much use of archival resources, and contain extensive bibliographies.

4762. Wallis, Ruth, and Peter Wallis. "Female Philomaths". *Historia Mathematica* 7 (1980), 57–64.

"The evidence from the *Ladies' Diary* . . . is extended, and other sources of information, particularly subscription lists, are discussed" in order to determine "the extent of women's interest in and practice of mathematics in Britain in the 18th century."

4763. *Women and Mathematics: A Critical Inquiry*. Special issue of *Philosophia Mathematica* 13/14 (1976–1977), 5–203.

Special issue of journal consisting of six articles on women in mathematics. Includes: "Some 'Forgotten' Women of Mathematics: A Who Was Who" by Grinstein, Louise S. (pp. 73–78), which gives short professional profiles of "a dozen women [who] have been selected arbitrarily as a representative group" of American and British contributors to mathematics; "Woman Ph.D.'s in Mathematics in USA and Canada: 1886–1973" by Amy C. King with Rosemary McCroskey (pp. 79–129), which lists 926 (of the more than 1200) women who earned Ph.D.'s in the period 1886–1973 with the year of degree, degree-granting institution, and area of specialization; and "Women in Mathematics: A Preliminary Selected Bibliography" by Paul J. Campbell and Louise S. Grinstein (pp. 171–203), which lists 70 women mathematicians, providing birth and death dates, nationality, areas of interest, and related reference material, as well as an extensive index of references including dictionaries, encyclopedias, books, and periodical literature.

Studies of Individual Mathematicians and Their Work

There is an extensive list of works about individual women mathematicians at the websites maintained by Marie Vitulli, †Women in Math Project†, //darkwing.uoregon.edu/∼wmnmath/, and by Larry Riddle, †Biographies of Women Mathematicians†, //www.scottlan.edu/lriddle/women/. Vitulli's site includes a section on "People" that contains biographies as well as links to other sites, including the one maintained by Riddle. Riddle's site contains short biographies of women mathematicians, most of which are written by undergraduate mathematics students at Agnes Scott College in Decatur, Georgia. Many schools and departments maintain websites that include information on individuals with a connection to the institution.

Obituaries of individuals may be found in publications of professional organizations. Some of these are listed in *Mathematical Reviews*; few are listed below.

Maria Gaetana Agnesi (1718–1799)

See also items 8, 4730, and 4732.

4764. Sampson, J. H. "Maria Gaetana Agnesi". In *Seminari di geometria. 1988–1991.* Bologna: Università degli studi di Bologna, Instituto di Geometria "L. Cremona," Dipartimento di Matematica, 1991, 145–167.

Includes a biographical sketch and a discussion of Agnesi's 1748 *Instituzioni Analitiche ad uso della Gioventù italiana.* Short version in English, without references and details, appears as "Maria Gaetana Agnesi" by J. H. Sampson in *Geometry and Complex Variables*, (Lecture Notes in Pure and Applied Mathematics 132) New York: Marcel Dekker, 1991, 323–327.

4765. Tilche, Giovanna. *Maria Gaetana Agnesi: La Scienziata Santa del settecento.* Milano: Rizzoli, 1984, 187 pp.

Biography of Agnesi with relatively little emphasis on mathematics. Contains list of her published work and details of contents of the relevant manuscript collection in Milan.

4766. Truesdell, C. "Maria Gaetana Agnesi". *Archive for History of Exact Sciences* 40 (1989), 113–142.

An interpretation that minimizes Agnesi's mathematical contributions and the influence of her 1748 text. Article contains little on the contents of the text. Corrections and additions appear in *Archive for History of Exact Sciences* 43 (1992), 385–386.

Gertrude Blanch (1897–1996)

4767. Grier, David Alan. "Gertrude Blanch of the Mathematical Tables Project". *IEEE Annals of the History of Computing.* 19 no. 4, (1997), 18–27.

Uses interviews and personal papers to describe Blanch's background, her work as leader of the Mathematical Tables Project, and her contributions to numerical analysis. The few comments made regarding the overall role of women in mathematics should be read with caution.

Hel Braun (1914–1986)

4768. Braun, Hel. *Eine Frau und die Mathematik 1933–1940: Der Beginn einer wissenschaftlichen Laufbahn.* Edited by Max Koecher. Berlin, New York: Springer-Verlag, 1990, vii + 76 pp.

Hel Braun's autobiographical report of her life as a mathematics student in Frankfurt, Marburg, and Göttingen from 1933 until her *Habilitation* in 1940.

Dame Mary Lucy Cartwright (1900–1998)

4769. McMurran, Shawnee L., and James J. Tattersall. "The Mathematical Collaboration of M. L. Cartwright and J. E. Littlewood". *American Mathematical Monthly* 103 (1996), 833–845.

Describes the ten-year collaboration between Cartwright and Littlewood that was begun before World War II. Their work was on the van der Pol equation, had application to radio amplifiers, and was relevant to the development of the theory of dynamical systems. See also article by the same authors, "Cartwright and Littlewood on van der Pol's Equation" in *Harmonic Analysis and Nonlinear Differential Equations* (Contemporary Mathematics 208) Providence, R.I.: American Mathematical Society, 1997, 265–276.

Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet (1706–1749)

See also items 8, 4730, and 4732.

4770. Cohen, I. Bernard. "The French Translation of Isaac Newton's Philosophiae Naturalis Principia Mathematica (1756, 1759, 1966)". *Archives Internationales d'Histoire des Sciences* 21 (1968), 261–290.

"Study devoted to the bibliographical questions relating to the various issues or editions of the translation . . . "

4771. Debever, R. "La Marquise du Châtelet traduit et commente les *Principia* de Newton". *Académie Royale de Belgique. Bulletin de la Classe des Sciences.* 5e Série 73 no. 12 (1987), 509–527.

Well documented biographical article with a description of du Châtelet's scientific works.

Maria Cibrario Cinquini (1905–1992)

4772. Magenes, Enrico. "Maria Cibrario Cinquini". *Atti della Accademia Nazionale dei Lincei. Classe di Scienze Fisiche, Matematiche e Naturali. Rendiconti Lincei.* Serie IX. Supplemento. 5 (1994), 35–47. In Italian.

Obituary of Italian analyst. Includes a list of her 101 publications.

Gertrude Mary Cox (1900–1978)

See also item 4730.

4773. Anderson, Richard L. "Gertrude Mary Cox, January 13, 1900–October 17, 1978". In *Biographical Memoirs, National Academy of Sciences of the United States of America, 59.* Washington, D.C.: National Academy Press, 1990, 117–132.

Personal recollections and description of Cox's scientific work in psychological statistics and experimental design and of her administrative activities. Includes a selected bibliography.

Hilda Geiringer (1893–1973)

See also item 4730.

4774. Binder, Christa. "Hilda Geiringer: Ihre ersten Jahre in Amerika". In *Amphora: Festschrift für Hans Wussing zu seinem 65. Geburtstag.* Edited by Sergei S. Demidov, Menso Folkerts, David E. Rowe, and Christoph J. Scriba. Basel: Birkhäuser Verlag, 1992, 25–53.

Includes a short biography of the Austrian-born applied mathematician Hilda Geiringer, as well as excerpts from letters written while she was in the U.S., most of which are in English.

4775. Siegmund-Schultze, Reinhard. "Hilda Geiringer-von Mises, Charlier Series, Ideology, and the Human Side of the Emancipation of Applied Mathematics at the University of Berlin during the 1920s". *Historia Mathematica* 20 (1993), 364–381.

Discusses Geiringer's *Habilitation* (the first for a woman at Berlin and the second for a woman, Noether being the first, in Germany) and the "ideological and disciplinary issues" that surrounded it. Incorporates material from a 71-page handwritten document "Mathematische Entwicklung", which was composed by Geiringer in about 1970.

Sophie Germain (1776–1831)

See also items 8, 4730, and 4732.

4776. Bucciarelli, Louis L., and Nancy Dworsky. *Sophie Germain: An Essay in the History of the Theory of Elasticity.* Dordrecht: D. Reidel Publishing Company, 1980, xi + 147 pp.

Discusses Germain's correspondence with Gauss and her contributions to number theory, as well as her better-known accomplishments in mathematical physics, for which she won the *prix extraordinaire* of the Institut de France in 1816. Contains some biographical information. See also item 3297 and review by Robert Fox in *Historia Mathematica* 11 (1984), 102–103.

4777. Dahan-Dalmédico, Amy. "Mécanique et théorie des surfaces: les travaux de Sophie Germain". *Historia Mathematica* 14 (1987), 347–365.

"This article sketches Sophie Germain's works on elastic surfaces, focusing on the role and justification of the fundamental hypothesis she made along the line of Euler's studies of sticks." The same author has published other articles on Germain, including "Sophie Germain", *Scientific American* 265 no. 6 (December 1991), 117–122, and "Sophie Germain: Une femme aux marges de la communaute scientifique" in *Histoire et épistémologie des mathématiques: les mathématiques dans la cultur d'une epoque* (Strasbourg: Université Louis Pasteur, Institut de recherche sur l'enseignement des mathématique, 1988), 18–54.

Grace Murray Hopper (1906–1992)

See also item 4732.

4778. Billings, Charlene W. *Grace Hopper: Navy Admiral and Computer Pioneer*. Hillside, N.J.: Enslow Publishers, Inc., 1989, 128 pp.

Short biography, written carefully and with the cooperation of Hopper. Includes a valuable resumé of her "education, military record, awards, and professional activities." Classified as juvenile literature.

Hypatia (370?–415)

See also items 8, 4730, and 4732.

4779. Deakin, Michael A. B. "Hypatia and Her Mathematics". *American Mathematical Monthly* 101 (1994), 234-243.

Focuses on the perceived limitations of previously published works about Hypatia.

4780. Dzielska, Maria. *Hypatia of Alexandria*. Translated by F. Lyra. Cambridge, Mass.: Harvard University Press, 1995, xii + 157 pp. .

Describes the literary legends that have grown up around Hypatia and attempts to reconstruct her life and work on the basis of extant materials. See review by Michael A. B. Deakin in *American Mathematical Monthly* 103 (1996), 83–87.

Sofia Kovalevskaia (1850–1891)

See also items 8, 4730, 4732, and 4761.

4781. Bölling, Reinhard, ed. *Briefwechsel zwischen Karl Weierstrass und Sofja Kowalewskaja*. Berlin: Akademie-Verlag, 1993, 504 pp.

Edition of Weierstrass' letters to Kovalevskaya that includes an introduction and commentary by the editor. Each letter is annotated, and there is a summary of the editor's reconstruction of the missing replies from Kovalevskaya. Appendices include an 1874 letter from H. A. Schwarz on Kovalevskaya's dissertation, an 1883 letter from Weierstrass to Mittag-Leffler on Kovalevskaya's appointment to the University in Stockholm, and a partial draft of an 1883 letter from Kovalevskaya. Correspondence between Kovalevskaya and Mittag-Leffler edited by A. P. Yushkevich appears in Russian in *Perepiska S. V. Kovalevskoj i G. Mittag-Leffler* (Moscow: "Nauka", 1984, 312 pp.). See review of the main item by Roger Cooke in *Historia Mathematica* 22

(1995), 73–77. This review cites other published versions of Kovalevskaya's correspondence.

4782. Cooke, Roger. *The Mathematics of Sonya Kovalevskaya.* New York-Berlin: Springer-Verlag, 1984, xiii + 234 pp.

Analysis of the mathematics of Kovalevskaya in the context of nineteenth-century analysis, with some biographical material and contemporary evaluation of her work. Has appendices to aid the reader and an extensive bibliography.

4783. Keen, Linda, ed. *The Legacy of Sonya Kovalevskaya. Proceedings of a Symposium Sponsored by The Association for Women in Mathematics and The Mary Ingraham Bunting Institute held October 25–28, 1985.* (Contemporary Mathematics 64.) Providence, R.I.: American Mathematical Society, 1987, xiv + 297 pp.

Includes three articles on Kovalevskaya's life and work: "Sofia Kovalevskaia – A Biographical Sketch" by Ann Hibner Koblitz (pp. 3–16), "Sonya Kovalevskaya's Place in Nineteenth-Century Mathematics" by Roger Cooke (pp. 17–51), and "Changing Views of Sofia Kovalevskaia" by Ann Hibner Koblitz (pp. 53–76). Also includes technical articles.

4784. Koblitz, Ann Hibner. *A Convergence of Lives. Sofia Kovalevskaia: Scientist, Writer, Revolutionary.* Boston: Birkhäuser, 1983, xx + 305 pp. 2nd ed. (Lives of Women in Science.) New Brunswick, N.J.: Rutgers University Press, 1993, xl + 305 pp.

Presents a "unified historical portrait" of Kovalevskaia using material from archives and libraries of Leningrad, Moscow, and Stockholm. Second edition is reprint of 1988 revised printing with an additional preface that discusses and critiques some of the more recent literature on women in science. It also notes studies of women in science in Asia and Central America. See review of the first edition by G. J. Tee in *Historia Mathematica* 13 (1986), 191–193. See also the Russian article by Koblitz, "New Material on S. V. Kovalevskaya", *Istoriko-Matematicheskie Issledovaniya* 32–33 (1990), 408–417, in which "new material" refers to documents in the Institut Mittag-Leffler in Djursholm, Sweden.

4785. Kochina, P. Ya. *Sof′ya Vasil′evna Kovalevskaya, 1850–1891.* Moscow: "Nauka", 1981, 312 pp.

Makes extensive use of correspondence and the Kovalevskaya archives of the Soviet Academy of Sciences. Has forty-four photographs of people and places significant in Kovalevskaya's life. A number of much earlier Russian and English versions of this work appeared starting in 1957. The (revised) English translation by Michael Burov appears as *Love and Mathematics: Sofya Kovalevskaya* by Pelageya Kochina (Moscow: "Mir", 1985, 346 pp.).

4786. Tuschmann, Wilderich, and Peter Hawig. *Sofia Kowalewskaja. Ein Leben für Mathematik und Emanzipation.* Basel: Birkhäuser Verlag, 1993, 185 pp.

A general biography that discusses many aspects of Kovalevskaya's life and work. See reviews by Reinhard Bölling in *Historia Mathematica* 22 (1995), 442–446, and by R. L. Cooke in **MR** 97a:01066 for differing assessments of this work.

Ol′ga Aleksandrovna Ladyzhenskaya (b. 1922)

4787. Aleksandrov, A. D., A. P. Oskolokov, N. N. Ural′tseva, and L. D. Faddeev. "Ol′ga Aleksandrovna Ladyzhenskaya (On the Occasion of her Sixtieth Birthday)". *Russian Mathematical Surveys* 38 no. 5 (1983), 171–181. Reprinted in *AWM Newsletter* 15 no. 2 (1985), 12–20.

A brief biographical account of Ladyzhenskaya. Includes discussion of her work on partial differential equations and a list of seventy-seven of her publications. The list contains items 86 through 162; items 1 through 85 appear in an earlier article in Russian.

Augusta Ada Byron, Lady Lovelace (1815–1852)

See also items 4748, 4730, and 4732.

4788. Huskey, Velma R., and Harry D. Huskey. "Lady Lovelace and Charles Babbage". *Annals of the History of Computing* 2 (1980), 299–329.

"This paper is centered on the correspondence that took place between Lady Lovelace and Charles Babbage, particularly during her writing of the . . . notes that accompany her translation of Menabrea's paper on Babbage's Analytical Engine. . . . Her mathematical background and studies are given in some detail." Based on papers in the Bodleian Library, Oxford University, and the British Library, London.

4789. Stein, Dorothy. *Ada: A Life and a Legacy.* (MIT Press Series in the History of Computing.) Cambridge, Mass.: MIT Press, 1985, xix + 321 pp.

Described in the author's preface as a "biography . . . of a figure whose achievement turns out not to deserve the recognition accorded it." Makes extensive use of primary sources to analyze Lovelace's personal life and her intellectual, including mathematical, development. See review by Karen Hunger Parshall in *Historia Mathematica* 16 (1989), 94–95.

4790. Toole, Betty A. *Ada, the Enchantress of Numbers: A Selection from the Letters of Lord Byron's Daughter and Her Description of the First Computer.* Mill Valley, Calif.: Strawberry Press, 1992, xvi + 439 pp.

Selections from 390 letters written between 1824 and 1852, from thousands written by Ada Byron Lovelace. Includes a selection from her notes relating to computing. Also includes introduction, commentary, illustrations, and annotated bibliography leading to other sources.

Ruth Moufang (1905–1977)

See also item 8.

4791. Srinivasan, Bhama. "Ruth Moufang, 1905–1977". *The Mathematical Intelligencer* 6 no. 2 (1984), 51–55.

Includes basic biographical information, a list of Moufang's papers, and a short discussion of her work, especially that concerned with finite projective planes. See the article by Irene Piper-Seier in item 4761 for a more detailed discussion of her life and work. It also includes copies of archival material and lists of her publications and doctoral students.

Hanna Neumann (1914–1971)

See also item 4730.

4792. Neumann, B. H., and Hanna Neumann. *Selected Works of B. H. Neumann and Hanna Neumann. Vols. I–VI.* Winnipeg, Manitoba: Charles Babbage Research Centre, 1988, lii + 1371 pp.

Includes an obituary of Hanna Neumann by M. F. Newman and G. E. Wall. Obituary by the same authors also appears as "Hanna Neumann", *Journal of the Australian Mathematical Society* 17 (1974), 1–28.

Emmy Noether (1882–1935)

See also items 8, 4730, and 4732.

4793. Brewer, James W., and Martha K. Smith, eds. *Emmy Noether: A Tribute to Her Life and Work.* New York: Marcel Dekker, 1981, x + 180 pp.

Includes a lengthy biographical essay by Clark Kimberling, "Emmy Noether and Her Influence" (pp. 3–61); personal reminiscences by Saunders Mac Lane, "Mathematics at the University of Göttingen (1931–1933)" (pp. 65–78), and Olga Taussky, "My Personal Recollections of Emmy Noether" (pp. 79–92); obituaries by B. L. van der Waerden, "Obituary of Emmy Noether" (pp. 93–98), and P. S. Alexandroff, "In Memory of Emmy Noether" (pp. 99–111); technical articles; a translation of Noether's address to the 1932 International Congress of Mathematicians; and a list of forty-four of her publications. The obituary by van der Waerden appeared in German in *Mathematische Annalen* 111 (1935), 469–476, while the memorial address by Alexandroff appeared in Russian in *Uspekhi Matematicheskikh Nauk* 2 (1936), 253–266. Different translations of these two articles appear in item 4794. See review by David E. Rowe in *Historia Mathematica* 10 (1983), 462–466.

4794. Dick, Auguste. *Emmy Noether, 1882–1935.* Translated by H. I. Blocher. Boston: Birkhäuser, 1981, xiv + 193 pp.

Updated English translation of a 1970 biography of Emmy Noether. It also includes an obituary by B. L. van der Waerden, "Obituary of Emmy Noether" (pp. 100–111); Hermann Weyl's memorial address at Bryn Mawr College, April 26, 1935, "Emmy Noether" (pp. 112–152), reprinted from *Scripta Mathematica* 3 (1935), 201–220; and a memorial speech by P. S. Alexandrov, "In Memory of Emmy Noether" (pp. 153–179). Alexandrov's article is newly added for this edition. Also includes lists of Noether's publications, dissertations completed under her direction, and obituaries. See the entry for item 4793 for the original publication data for the articles by van der Waerden and Alexandrov. See the review by David E. Rowe in *Historia Mathematica* 10 (1983), 462–466.

4795. Kleiner, Israel. "Emmy Noether: Highlights of Her Life and Work." *L'Enseignement Mathématique* 38 no. 1–2 (1992), 103–124.

Includes a brief biography and a discussion of her work in the areas of invariant theory, commutative algebra, noncommutative algebra and representation theory, and applications of noncommutative to commutative algebra, along with a brief section on her legacy. Also appears in *Proceedings of the Canadian Society for the History and Philosophy of Mathematics* 4 (1991), 19–42.

4796. Noether, Emmy. *Gesammelte Abhandlungen.* Berlin: Springer-Verlag, 1983, viii + 777 pp.

Edited and with an introduction by Nathan Jacobson. Includes an introductory address by P. S. Alexandrov.

4797. Srinivasan, Bhama, and Judith D. Sally, eds. *Emmy Noether in Bryn Mawr. Proceedings of a Symposium Sponsored by the Association for Women in Mathematics in Honor of Emmy Noether's 100th Birthday.* New York: Springer-Verlag, 1983, viii + 182 pp.

Includes technical articles; a historical article on Noether, "Emmy Noether in Erlangen and Göttingen" by Emiliana P. Noether and Gottfried E. Noether (pp. 133–137); personal reminiscences, "Emmy Noether in Bryn Mawr" by Grace S. Quinn, Ruth S. McKee, Marguerite Lehr, and Olga Taussky (pp. 139–146); and related historical articles by Jeanne LaDuke and Uta C. Merzbach. Also includes a complete bibliography of Noether's works compiled by Uta C. Merzbach (pp. 173–182).

4798. Tollmien, Cordula. "Die Habilitation von Emmy Noether an der Universität Göttingen". *NTM Schriftenreihe für Geschichte der Naturwissenschaften Technik und Medizin* 28 no. 1 (1991), 13–32.

Uses archival material to discuss in detail Noether's *Habilitation*, the history of the *Habilitation* of women, and the attitudes of various

Göttingen faculty toward women in academia.

Olga Oleinik (b. 1925)

4799. Magenes, E. "On the Scientific Work of Olga Oleinik". *Rendiconti di Matematica e della sue Applicazioni. Serie VII.* 16 no. 3 (1996), 347–373.

Survey of Oleinik's work in differential equations. Contains a selected list of 124 of Oleinik's works.

Rózsa Péter (1905–1977)

See also item 4730.

4800. Morris, Edie, and Leon Harkleroad. "Rózsa Péter: Recursive Function Theory's Founding Mother". *The Mathematical Intelligencer* 12 no. 1 (1990), 59 & 61.

Describes Péter's contributions as the founder of the field of recursive function theory as well as some of the honors she received. See also article by László Kalmár, "R. Péter's Work in the Theory of Recursive Functions", in *Les Fonctions Recursives et Leurs Applications* (l'Institut Blaise Pascal and the János Bolyai Mathematical Society, 1969).

Helena Rasiowa (1917–1994)

See also item 4758.

4801. Bartol, Wictor, Ewa Orlowska, and Andrzej Skowron. "Helena Rasiowa, 1917–1994". *Modern Logic* 5 (1995), 231–247.

Obituary. Rasiowa's early work in algebraic logic and her later work in the mathematical foundations of computer science are discussed. Includes a partial bibliography.

Julia Robinson (1919–1985)

See also items 4730 and 4732.

4802. Reid, Constance, ed. *Julia: A Life in Mathematics.* Washington, D.C.: Mathematical Association of America, 1996, xi + 124 pp.

Includes four previously published articles: "The Autobiography of Julia Robinson" by Constance Reid (pp. 1–82), adapted from *More Mathematical People*, edited by Donald J. Albers, Gerald L. Alexanderson, and Constance Reid, (Boston, Mass.: Harcourt Brace Jovanovich, 1990), 262–280; "Julia Robinson's Dissertation" by Lisl Gaal (pp. 85–89), adapted from *AWM Newsletter* 16 no. 3, (1986), 6–8; "The Collaboration in the United States" by Martin Davis (pp. 91–97), excerpted from the foreword to *Hilbert's Tenth Problem* by Yuri Matijasevich, (Cambridge, Mass.: MIT Press, 1993); and "My Collaboration with Julia Robinson" by Yuri Matijasevich (pp. 99–116), reprinted with corrections from *The Mathematical Intelligencer* 14 no. 4 (1992), 38–45; erratum 15 no. 1 (1993), 75. Includes many photos, some not previously published. Another version of "The Autobiography of Julia Robinson" by Constance Reid appears in *College Mathematics Journal* 17 (1986), 2–21.

4803. Robinson, Julia. *The Collected Works of Julia Robinson.* Edited by Solomon Feferman. Providence, R.I.: American Mathematical Society, 1996, xliv + 338 pp.

Contains the twenty-five published papers of Robinson. Includes an introduction by Constance Reid and a reprint of the National Academy of Sciences memorial article by Solomon Feferman, "Julia Bowman Robinson, December 8, 1919–July 30, 1985", in *Biographical Memoirs, National Academy of Sciences of the United States of America 63* (Washington, D.C.: National Academy Press, 1994), 452–478. This article focuses on Robinson's work in "effective solvability and unsolvability of various mathematical problems, as well as with the characterization of various notions of effectiveness."

Charlotte Angas Scott (1858–1931)

See also items 4730 and 4732.

4804. Kenschaft, Patricia C. "Charlotte Angas Scott, 1858–1931". *College Mathematics Journal* 18 (1987), 98–110.

Mainly biographical. Includes a short discussion of Scott's work and a complete bibliography.

4805. Macaulay, F. S. "Dr. Scott Charlotte Angas". *Journal of the London Mathematical Society* 7 (1932), 230–240.

Obituary describing C. A. Scott's mathematics. Includes publication list.

Olga Taussky-Todd (1906–1995)

See also item 4732.

4806. Taussky-Todd, Olga. "Olga Taussky-Todd: An Autobiographical Essay". In *Mathematical People.* Edited by Donald J. Albers and Gerald L. Alexanderson. Cambridge, Mass.: Birkhäuser Boston, 1985, 309–336.

"This personal memoir was written by Olga Taussky-Todd at the request of the Oral History Project of the Caltech Archive. . . " It contains descriptions of her childhood, and her study and work, especially in Vienna; Göttingen; Bryn Mawr; Cambridge, at Girton College; Washington, D.C., at the National Applied Mathematics Laboratory of the National Bureau of Standards; and Pasadena, at Caltech.

Anna Pell Wheeler (1883–1966)

See also item 4730.

4807. Grinstein, Louise S., and Paul J. Campbell. "Anna Johnson Pell Wheeler: Her Life and Work." *Historia Mathematica* 9 (1982), 37–53.

Includes a discussion of Pell Wheeler's work in linear algebra and integral equations and of the recognition she received within the mathematical community. Also contains a list of her doctoral students and a complete bibliography of her published work.

Grace Chisholm Young (1868–1944)

See also items 4730 and 4732.

4808. Grattan-Guinness, Ivor. "A Mathematical Union: William Henry and Grace Chisholm Young". *Annals of Science* 29 (1972), 105–184.

Based mainly on family documents and letters, as well as much autobiographical material by Grace Chisholm Young. For the Youngs' mathematical works see "Mathematical Bibliography of W. H. and G. C. Young" by Ivor Grattan-Guinness, *Historia Mathematica* 2 (1975), 43–58.

4809. Wiegand, Sylvia. "Grace Chisholm Young and William Henry Young: A Partnership of Itinerant British Mathematicians". In *Creative Couples in the Sciences.* Edited by Helena M. Pycior, Nancy G. Slack, and Pnina G. Abir-Am. New Brunswick, N.J.: Rutgers University Press, 1996, 126–140.

Outlines the basic details of the lives and work of the Youngs. Uses family correspondence to explore the nature of their personal relationship and mathematical collaboration.

MATHEMATICS AND MUSIC

A search under "music" will reveal a number of works in other sections.

4810. Dostrovsky, Sigalia. "Early Vibration Theory: Physics and Music in the Seventeenth Century". *Archive for History of Exact Sciences* 14 (1975), 169–218.

Extract of the author's dissertation 3298.

4811. Götze, Heinz, and Rudolf Wille, eds. *Musik und Mathematik. Salzburger Musikgespräch 1984 unter Vorsitz von Herbert von Karajan.* Berlin, Heidelberg, New York, Tokyo: Springer-Verlag, 1985, ix + 97 pp.

Eight contributions on the relation between mathematics and music in history, from the Pythagoreans to the application of electronic computers.

4812. James, Jamie. *The Music of the Spheres. Music, Science, and the Natural Order of the Universe.* New York: Copernicus, an imprint of Springer-Verlag, 1993, xvii + 263 pp.

The author, a New York music critic and journalist of science, relates "the parallel histories of music and science—from celestial harmony to cosmic dissonance." A non-mathematical, but thought-provoking reassessment of the Western musical tradition and its relation to science, from Pythagoras to Schönberg and Hindemith.

4813. Knobloch, Eberhard. "Desargues, Mersenne et Kircher: la musique et les mathématiques". In *Desargues en son temps*, Paris: Libr. Sci. A. Blanchard, 1994, 111–124.

Two aspects of Book Six ("The book on the art of singing well") from Marin Mersenne's *Harmonie universelle* (1636).

NUMEROLOGY, GEMATRIA AND GEOMETROLOGY

See also sub-sections in other sections on architecture.

4814. Albarn, K., J. Miall Smith, S. Steel and D. Walker. *The Language of Pattern*. London: Thames and Hudson, 1974.

Modern study of pattern inspired by numerology in Islamic decoration.

4815. Bannister, T. C. "The Constantine Basilica of Saint Peter in Rome". *Journal of the Society of Architectural Historians* 27 (1968), 3-32.

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4816. Buchor, F. *Architector. The Lodgebooks and Sketchbooks of Medieval Architects*. New York: Abaris, 1979.

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4817. Cavendish, R. *The Tarot*. London: Michael Joseph, 1975.

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4818. Dehio, Georg Gottfried. *Untersuchungen über das gleichseitige Dreieck als Norm gotischer Bauproportion*. Stuttgart: Cotta, 1894.

Wide range of analyses showing the use of the equilateral triangle. Also various related forgotten essays by this author.

4819. Dornseiff, F. *Das Alphabet in Mystik und Magie*. Leipzig: Teubner, 1922. 2nd ed.1925.

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4820. Fleming, A. "Number in Nature and in the Biblical Literature Indicating a Common Origin in a Supreme Intelligence". *Transactions of the Victoria Institute* 60 (1928), 11-44 (including discussion).

4821. Ghyka, M. *Le nombre d'or. Rites et rhythmes pythagoriciens dans le développement de la civilisation occidentale*. Paris: Gallimard, 1931. 2 vols.

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4822. Grattan-Guinness, I. "Mozart 18, Beethoven 32: Hidden Shadows of Integers in Classical Music". In *the History of Mathematics: States of the Art*. Edited by J. W. Dauben, M. Folkerts, E. Knobloch, and H. Wussing. Boston: Academic Press, 1996, 29-47.

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4823. Hopper, V. F. *Medieval Number Symbolism, Its Sources, Meaning and Influence on Thought and Expression.* New York: Cooper Square, 1938. Reprinted 1969.

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4824. Iamblichus. *The Theology of Arithmetic.* Translated by R. Waterfield. Grand Rapids, Michigan: Phanes, 1988.

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4825. James, John *The Contractors of Chartres.* Vol. 1. Dooralong, Australia: Mandorla; London: Croom Helm, 1978.

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4826. Le Corbusier. *The Modulor.* Cambridge, Mass.: Harvard University Press, 1954. 1st edition Paris, 1951, in French.

Use of Fibonacci series.

4827. Lendvai, E. *Béla Bartók. An Analysis of His Music.* London: Kahn and Everill, 1971.

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4828. Lesser, G. *Gothic Cathedrals and Sacred Geometry.* London: Tiranti, 1957-1964. 3 vols.

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4831. Quinn, M. *The Swastika. Constructing the Symbol.* London: Routledge, 1994.

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4832. Roscher, W. H. *Die Sieben- und Neunzahl im Kultus und Mythus.* Leipzig: Teubner, 1904.

One of several important neglected essays on the significance of 7 and 9 in Greek thought.

4833. Scholem, G. "Gematria". In *Encyclopaedia Judaica.* Vol. 4. Jerusalem: Keter, 1971, cols. 369-374.

Also other articles in this publication, several by this author.

AUTHOR INDEX
Includes authors, editors, translators.

SUBJECT INDEX

Lists names which appear in titles and annotations.