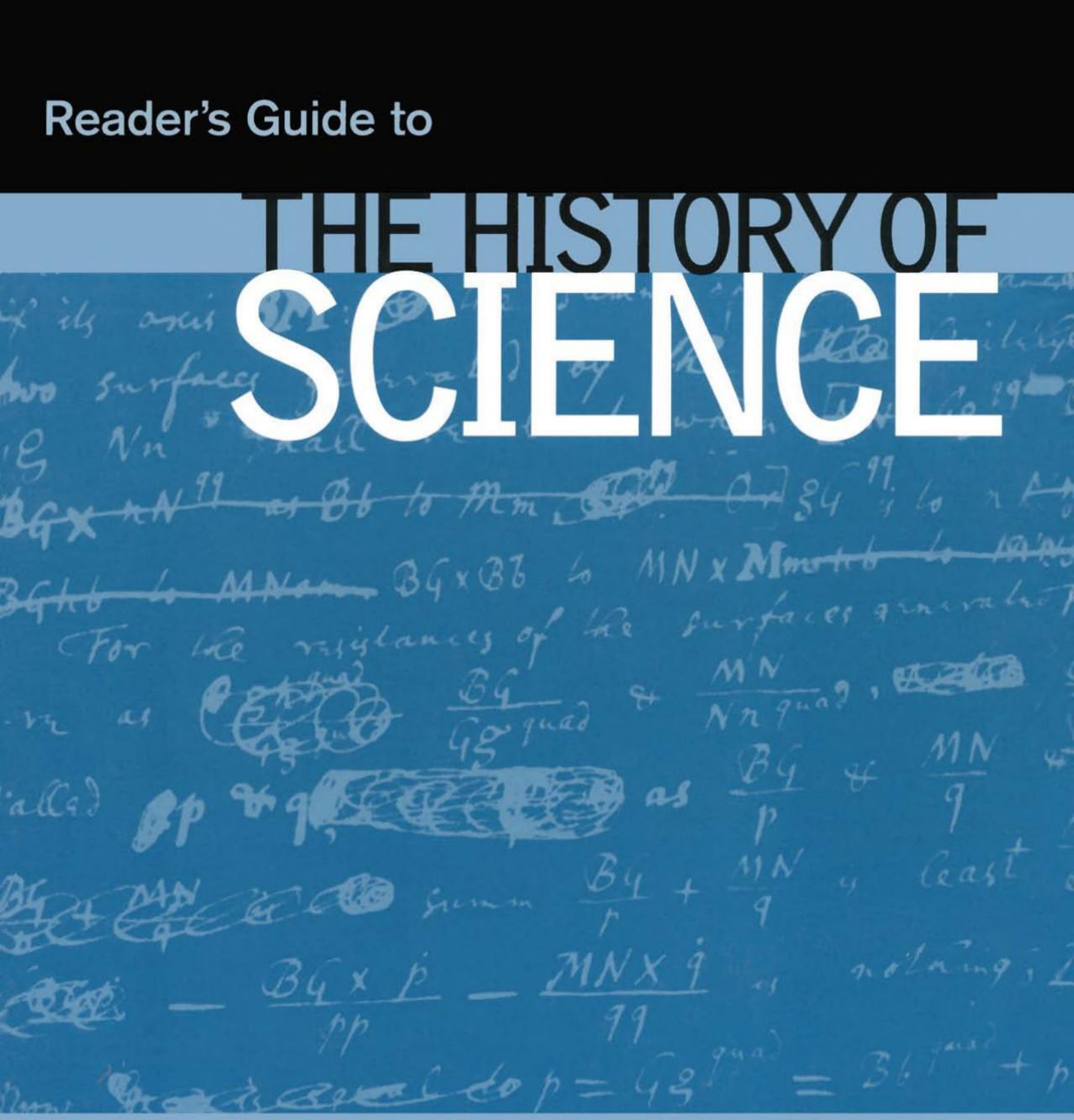
Reader's Guide to

THE HISTORY OF SCIENCE



Edited by Arne Hessenbruch

Reader's Guide to the

History of Science

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EDITOR'S NOTE

Aims, Scope, and Selection of Entries

The subject of the history of science has come of age. One can speak almost of a torrent of new books on the topic, especially if one includes the history of technology and medicine, as in this book. Among them are admirable examples of readable and authoritative treatments of large topics, addressed to a wide audience. However, a great deal of the recent work has reflected intense specialization within the subject; professional historians of science have increasingly been producing monographs addressed to a relatively restricted audience of fellow-specialists and their graduate students. However, it has become impossible to digest the literature in all subdisciplines, even for professional historians of science, while many of these debates have become confusing or even mystifying to a wider readership.

One positive feature, however, is the widening range of the historiography. What used to be called internal history remains important, but it is now complemented by a great diversity of other approaches. One can say generally that the 1980s saw a clash of traditional historiography with the sociology of science. In the 1990s debates on the role of gender in the history of science arrived on the scene, and now the cultural history of science has entered the mainstream. In future, this ought to enable mutual stimulation to a greater extent than is currently the case.

The aim of the *Reader's Guide to the History of Science* is to offer some help to those who wish to explore the riches of the writings on history of science in all its diversity. In the belief that a simple listing of books will not suffice for this purpose, the *Reader's Guide* takes the form of a series of essays that describe and assess books on some 500 different topics – some specialized and very specific, others much broader and more general. This approach is designed to help readers of various kinds and at various levels: students (both undergraduate and graduate) looking for assistance with their next assignment or research paper; teachers in schools, colleges and universities – and particularly those who are faced with the challenge of preparing courses or classes on topics in which they are not specialists; and those non-specialist readers who simply have an interest in a particular subject, and seek advice on what to read next.

Entries fall into three main categories, dealing respectively with individuals, disciplines and institutions, and broader themes. In cases where the literature on particular individuals is not substantial it has been subsumed under a broader theme. For instance, there are several entries entitled Women in Science (subdivided by discipline, for example, the physical sciences, medicine, life sciences) which collect the literature on individual women on whom too little has appeared to warrant an individual entry. The second

category reflects another important genre. There are many histories of disciplines such as genetics, biology, physics, and chemistry, and of institutions such as the Royal Society of London. The third, more general, category covers literature on topics such as the Enlightenment or the Scientific Revolution. This category also contains entries on analytical concepts, such as Alienation, Discovery, and Experiments. The aim overall is that this kind of "multi-layered" approach will enable the user to navigate from the particular to the general, or vice versa, as his or her needs and inclinations dictate.

Even a volume with the generous proportions of this *Reader's Guide* cannot hope to be comprehensive in its coverage or in its treatment of each topic. Lines had to be drawn to make the project manageable within the scope of a single volume. Given that the approach had to be selective, the reader is entitled to know something of the principles underlying that selection. These are:

1. The emphasis is predominantly on books (and contributions to books), as opposed to articles in journals and magazines. Articles are normally included only when they are of seminal importance, or when there is no adequate treatment of a particular aspect of a subject in a book-length study.
2. The *Reader's Guide* is a guide to the secondary literature, and not to primary sources, or to collections of printed source material. There are two limited exceptions to this rule. An editorial introduction or editorial footnotes to a collection of source materials may justify the inclusion of the source materials. Second, translations of primary source material are included too.
3. For each entry, the contributor was free, within the editorial guidelines, to make his or her own choice of books to be discussed. In most cases, the emphasis is on more recently published work, but, where appropriate contributors were encouraged to include earlier books in order to sketch the historiographical development. New works appear constantly, and there has been no single cut-off point for inclusion of books in the *Reader's Guide*.

I would like to think of the *Reader's Guide* as a snapshot of the history of science at the beginning of the 21st century.

Arrangement of the Entries

Entries appear in alphabetical order; a complete list of them can be found in the **Alphabetical List of Entries** (p. xv). Where entries share the same general heading (e.g., China, Japan, Religion and Science), if there is a "general works" entry in such a group, it always precedes more specific subdivision.

While the overall arrangement of entries is alphabetical, there are other aids to facilitate access to the contents of the *Reader's Guide*. These are:

1. **Thematic List** (p. xxi). This should be consulted to see the full range of entries in the *Reader's Guide* on a particular subject area such as Institutions or Physical Sciences.
2. **Booklist Index** (p. 773). This lists in alphabetical order of author all books and articles discussed in any of the entries, and can be used to locate discussion of the work of particular historians.

3. **General Index** (p. 829). This lists individuals, themes and concepts mentioned in any of the entries. This index may be particularly useful for locating references to subject matters and individuals that do not have an entry of their own.
4. **Cross references.** At the end of the entries there are *See also* notes, which refer the reader to entries on related topics.

Format within Entries

Each entry begins with a list of the books/articles to be discussed. Publication details are provided, including dates of first publication and, where appropriate, the most recent revised edition. Reprints and paperback editions are normally omitted. In the text of each essay, the first significant mention of each author appears in capital letters. In cases where more than one item by the same author is discussed in the same entry, each item is introduced by the author's name in capital letters, followed by date of publication in parentheses. In a few cases, this would still be ambiguous, and here key words from the title are used instead of the year of publication. Although the list of books in each entry proceeds in alphabetical order of author, books are normally not discussed in the text in that order. It was left to the judgment of contributors to decide whether to discuss books in order of publication, or, more often, according to the subject matter and emphasis of each book.

Acknowledgements

Although, in his darker moments, the editor felt that this project sucked the life-blood out of him, he wishes to acknowledge the help that he received from a great number of people. First, I should like to thank all those who have written for this volume. I am deeply impressed with the generosity and professionalism of those who offered to contribute entries, in some cases many entries, and who encouraged others to do so also. In this respect a special thanks is due to Rhodri Lloyd Hayward. I am grateful to many of my friends and colleagues who have worked long and hard to help in different ways. The Advisers, some of whom I am also happy to count as my friends, were extremely helpful, both in the selection of entries to be included in the *Reader's Guide* and in aiding me in the search for contributors. I would also like to thank my mother who has helped me in more ways than I could possibly articulate.

The resources of many libraries but especially the Cambridge University Library and the Whipple Library of Cambridge University have been invaluable. I have also been able to make very good use of the Eureka database of the History of Science Society. It is interesting to ponder the role of the electronic media in the making of this book. When the project started, Fitzroy Dearborn did not have an email address, nor could they envisage a need for it. Contributions were received as typescript and sometimes on disk. Now, only a few years later, contributions are communicated as email attachments keeping the formatting intact. To begin with I checked all items against actual books, paper catalogues or computer catalogues in libraries, by the end of the project I received contributions and checked references without leaving my computer.

Particular thanks goes to Lesley Henderson at Fitzroy Dearborn whose unfailing good spirit and calm sense of what needs to be done saw me through moments of despair.

Thanks are also due to the editorial and production staff at Fitzroy Dearborn, and especially to Nina Bunton, Antonella Elisabetta Collaro, Jonathon Dore, Carolyn Dorée, Delia Gaze, Jill Halliday, Gillian Lindsey, Helena Lyons, and Michael Wardle.

The main midwives of the book are my children, Anna and Eric, who have always been able to dispel any sense of doom. At the age of seven Anna replied to the question of what she wanted to do as a grown-up: "I want to write a book this thick", indicating with her hands the approximate dimensions of the present *Reader's Guide*.

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ALPHABETICAL LIST OF ENTRIES

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THEMATIC LIST

Entries by Category

Alternative Sciences

Analytical Concepts

Astronomy and Astrophysics

Almanacs
Astronomical Instruments
Astronomy: general works
Astronomy: non-European
Astrophysics
Big Bang Theory
Tycho Brahe
Nicolaus Copernicus
Cosmology
Galileo Galilei
Carl Friedrich Gauss
George Ellery Hale
Edmond Halley
William Herschel
Johannes Kepler
Particle Physics
Lambert Adolphe Jacques Quételet
David Rittenhouse
Space Science
Women in Science: astronomy

Chemical Sciences

Affinity
Alchemy
Atomism
Amedeo Avogadro
Adolf von Baeyer
Claude-Louis Comte de Berthollet
Jöns Jacob Berzelius
Biochemistry
Chemical Analysis
Chemical Revolution
Chemistry
Colloid Chemistry
Marie Curie
Humphry Davy
Drugs
Dyestuffs
Michael Faraday
Emil Fischer
Joseph Louis Gay-Lussac
Otto Hahn
Dorothy Hodgkin
Industrial Chemistry
Antoine Laurent Lavoisier
Justus von Liebig
Dmitrii Ivanovich Mendeleev
Walther Nernst
Organic Chemistry
Wilhelm Ostwald
Louis Pasteur
Pharmacology
Plastics and Polymers
Joseph Priestley
Carl Wilhelm Scheele
Spectroscopy
Valence
Women in Science: chemical sciences

Earth Sciences

Age of the Earth
Georgius Agricola
Agriculture
William Buckland
Cartography
Continental Drift
Georges Cuvier
Environmental Sciences
Geography of the Sciences
Geology
James Hutton
Charles Lyell
Meteorology
Oceanography
Paleontology
Physical and Human Geography
Niels Stensen

Education

Académie des Sciences
Accademia dei Lincei
Accademia del Cimento
CERN
École Polytechnique
Education
Engineering Schools
France: scientific and technical education
Gesellschaft Deutscher Naturforscher und Ärzte
Jesuits
Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften
Muséum National D'Histoire Naturelle
Physikalisch-Technische Reichsanstalt
Scientification of Education
Universities

Engineering and Technology

General Themes

Individuals

George Ellery Hale
Edmond Halley
William Harvey
Friedrich August von Hayek
Werner Heisenberg
Hermann von Helmholtz
William Herschel
Heinrich Rudolf Hertz
David Hilbert
Hippocrates
Dorothy Hodgkin
Joseph Dalton Hooker
Alexander von Humboldt
John Hunter
James Hutton
Thomas Huxley
Christiaan Huygens
Carl Gustav Jung
Immanuel Kant
Johannes Kepler
John Maynard Keynes
Melanie Klein
Robert Koch
Max von Laue
Antoine Laurent Lavoisier
Ernest Orlando Lawrence
Gottfried Wilhelm Leibniz
Leonardo da Vinci
Claude Lévi-Strauss
Justus von Liebig
Carl Linnaeus
Joseph Lister
Konrad Lorenz
Charles Lyell
Trofim Denisovich Lysenko
Ernst Mach
Thomas Malthus
Etienne-Jules Marey
Alfred Marshall
Harriet Martineau
Karl Marx
Pierre-Louis Moreau de Maupertuis
James Clerk Maxwell
Lise Meitner
Gregor Mendel
Dmitrii Ivanovich Mendeleev
Marin Mersenne
Albert A. Michelson
John Stuart Mill
Robert Andrews Millikan
Gaspard Monge
John Napier
Walther Nernst
Salomon Neumann
Isaac Newton
J. Robert Oppenheimer
Hans Christian Ørsted
Wilhelm Ostwald
Paracelsus
Louis Pasteur
Ivan Petrovich Pavlov
Karl Pearson
Jean Piaget
Max Planck
Plato
Jules Henri Poincaré
Joseph Priestley
Pythagoras
Lambert Adolphe Jacques Quételet
Chandrasekhara Venkata Raman
Santiago Ramón y Cajal
David Rittenhouse
Wilhelm Conrad Röntgen
Henry Augustus Rowland
Ernest Rutherford
Carl Wilhelm Scheele
Friedrich Wilhelm Joseph von Schelling
Erwin Schrödinger
Seki Kowa
Werner von Siemens
Adam Smith
Herbert Spencer
Niels Stensen
Thomas Sydenham
J.J. Thomson
Alan Turing
Andreas Vesalius
Rudolf Virchow
Alessandro Volta
John Von Neumann
James Watt
William Whewell

Life Sciences

Aristotle
Bacteriology
Karl Ernst von Baer
Joseph Banks
Emil von Behring
Biochemistry
Biometrics, Statistical Biology, and Mathematical Statistics
Biotechnology
Botany: general works
Botany: Britain
George-Louis Leclerc, Comte de Buffon
Charles Darwin
Darwinism
Darwinism in Germany
DNA
Ecology
Embryology
Endocrinology
Ethology and Animal Behaviour
Eugenics
Evolution
Evolutionary Synthesis
Alexander Fleming
Francis Galton
Luigi Galvani
Genetic Engineering
Genetics: general works
Genetics: post-DNA
Ernst Haeckel
William Harvey
Heredity
Joseph Dalton Hooker
Horticulture
Human Genome Project
Alexander von Humboldt
John Hunter
Thomas Huxley
Robert Koch
Carl Linnaeus
Konrad Lorenz
Trofim Denisovich Lysenko
Etienne-Jules Marey
Gregor Mendel
Molecular Biology
Natural Selection
Ornithology
Paleontology
Louis Pasteur
Ivan Petrovich Pavlov
Physiology: France
Physiology: Germany
Santiago Ramón y Cajal
Niels Stensen
Respiration
Taxonomy
Veterinary Science
Andreas Vesalius
Virology
Vitalism
Women in Science: life sciences

Literature of Science

Almanacs
Encyclopedias
Journals
Literature and Science
Reading Culture and Science
Science Fiction

Mathematical Sciences

Accountancy
Algebra
Archimedes
Arithmetic
Artificial Intelligence
Axiomatics
Biometrics, Statistical Biology, and Mathematical Statistics
Calculating Devices
Georg Cantor
Chaos Theory
Computing
John Dee
René Descartes
Ethnomathematics
Euclid
Pierre Fermat
Function
Francis Galton
Carl Friedrich Gauss
Geometry
Kurt Gödel
Group Theory
David Hilbert
Christiaan Huygens
Gottfried Wilhelm Leibniz
Mathematical Instruments
Mathematical Modernity
Pierre-Louis Moreau de Maupertuis
Marin Mersenne
Gaspard Monge
John Napier
Number Theory
Karl Pearson
Jules Henri Poincaré
Probability
Pythagoras
Lambert Adolphe Jacques Quételet
Rational Mechanics
Seki Kowa
Set Theory
Statistics
Alan Turing
John Von Neumann

Medical and Health Sciences

Acupuncture
AIDS
Anatomy
Anti-Vivisection
Asylums
Claude Bernard
Marie François Xavier Bichat
Birth Control
The Body
Herman Boerhaave
Cancer
Cardiology
Jean-Martin Charcot
Clinical Science
Clinical Trials
Complementary Medicine
Dentistry
Doctor–Patient Relationship
Drugs
Paul Ehrlich
Embryology
Endocrinology
Epidemics
Epidemiology
Experimental Physiology
Fevers
Alexander Fleming
Howard Walter Florey
Forensic Sciences
Galen
Gynaecology
William Harvey
Health, Mortality, and Social Class
Herbalism
Hippocrates
Histology
Holistic Medicine
Homoeopathy
Human Genome Project
John Hunter
Hysteria
Immunology
Joseph Lister
Madness
Malaria
Medical Ethics
Medical Specialization
Medicine and Law
Medicine, Disease, and Health
Salomon Neumann
Neurosciences
Nursing
Nutrition
Obstetrics and Midwifery
Pain
Paracelsus
Pathology
Pharmacy
Plastic Surgery
Psychiatry
Psychoanalysis: conceptual
Psychoanalysis: gender
Psychoanalysis: institutional
Psychology
Public Health
Radiology
Reproductive Medicine
Sexuality
Surgery
Thomas Sydenham
Toxicology
Traditional Medicine
Andreas Vesalius
Rudolf Virchow
Virology

Medicine and Society

National Histories

Physical Sciences

Science in "pre-modern" Cultures

Scientific Instruments

Social Sciences

Societies and Institutions

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A

Académie des Sciences

Académie des Sciences, *Index biographique de l'Académie des Sciences du 22 decembre 1666 au 1er octobre 1978*, Paris: Gauthier-Villars, 1979

Briggs, Robin, "The Académie Royale des Sciences and the Pursuit of Utility", *Past and Present*, 131 (1991): 38–88

Crosland, Maurice P., *Science under Control: The French Academy of Sciences, 1795–1914*, Cambridge and New York: Cambridge University Press, 1992

Gillispie, Charles Coulston, *Science and Polity in France at the End of the Old Regime*, Princeton, New Jersey: Princeton University Press, 1980

Hahn, Roger, *The Anatomy of a Scientific Institution: The Paris Academy of Sciences, 1666–1803*, Berkeley: University of California Press, 1971

McClellan III, James E., "The Académie Royale des Sciences, 1699–1793: A Statistical Portrait", *Isis*, 72 (1981): 541–67

McClellan III, James E., *Science Reorganized: Scientific Societies in the Eighteenth Century*, New York: Columbia University Press, 1985

Outram, Dorinda, "The Ordeal of Vocation: The Paris Academy of Sciences and the Terror", *History of Science*, 21 (1983): 251–95

Paul, Charles B., *Science and Immortality: The Éloges of the Paris Academy of Sciences, 1699–1791*, Berkeley: University of California Press, 1980

Salomon-Bayet, Claire, *L'Institution de la science et l'expérience du vivant: Méthode et expérience à l'Académie royale des sciences 1666–1793*, Paris: Flammarion, 1978

Stroup, Alice, *Royal Funding of the Parisian Académie des Sciences during the 1690s*, (Transactions of the American Philosophical Society, 77/4) Philadelphia: American Philosophical Society, 1987

Stroup, Alice, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences*, Berkeley: University of California Press, 1990

Louis XIV and Jean-Baptiste Colbert founded the original Académie royale des sciences in 1666; since then it has occupied a distinguished place in the history of science and scientific institutions.

The Paris Academy was a new kind of scientific institution in the 17th century: an official organ of state devoted explicitly to the sciences. With academicians paid and research underwritten, the Paris institution was distinct from the traditional universities and from the Renaissance-style academies that preceded it. Reformed in 1699, the Academy ranked foremost among the great classical academies of the 18th century in terms of its membership, publications, expeditions, and research undertaken under its aegis. Closed by revolutionaries in 1793 and resurrected in 1795 as the First Class of the Institut de France, it continued after another constitution in 1803 as the Académie (or Académie royale) des sciences of the Institut, and so led French science in the 19th century. The Academy of Science is the premier scientific institution in France today and, along with the Royal Society of London (1662), the *grande dame* of learned scientific societies.

The Paris Academy has been thoroughly studied, and scholars have documented most stages in its long and distinguished history. In the 19th and early 20th centuries, the Academy itself and persons close to it produced a substantial body of work concerning the institution that serious students still need to consult. (That literature is accessible through more recent scholarly work discussed in this essay.) In this tradition the biographical index of members published by the ACADÉMIE DES SCIENCES remains an important resource for information about the institution and its members. In more recent years, however, a series of independent, professional historians of science has focused on the Academy, and it is through their studies that one should now broach the historiography.

HAHN remains the entry point for the history of the Academy from its foundation in 1666 to the early years of the 19th century. He underscores the distinct 17th-century phase of the Academy's history until its reform in 1699, and argues that the weaknesses of the Academy during this period stem from its "closed" nature (it met privately and published little), and from the failure of its early commitment to collective Baconian endeavors. Through her careful sifting of the financial records, STROUP (1987) clarifies the circumstances of the 17th-century Academy, documenting the erratic and often miserly support from the crown that also limited the Academy's initial effectiveness. STROUP (1990) covers much the same ground but with an important emphasis on botany and the life sciences in the early period of the institution's history. SALOMON-BAYET addresses the theme of experimentation in the life sciences in the shadow of the Academy with Foucauldian epistemological sophistication, illuminating the institution from the point of view of the life sciences across

the 17th and 18th centuries. The pre-1699 phase of the Academy's history is now fairly well understood, although a full modern study of the Academy's early work in astronomy and geodesy remains to be written.

The formal reorganization of the Academy in 1699 created distinct categories of elected members and disciplinary fields, and otherwise transformed the institution into an active scientific center whose function was to judge and disseminate the approved scientific work of others. In its ensuing 18th-century phase the Academy reigned as Europe's leading scientific society, and this aspect of its history is the best studied. HAHN's focus is on the solidification of the Academy as an institution of the *ancien régime* in France and its travails to and through the revolutionary period. GILLISPIE provides additional context, and both emphasize the role of the Academy as a government institution providing technical and other useful services in exchange for the freedom to govern itself and science. Among the special studies of the Academy in the 18th century one needs to cite PAUL on the *éloges* of academicians published in the Academy's *Mémoires*; Paul underscores the rhetorical and ideological function of these *éloges* in helping to shape the modern image of science and scientists. McCLELLAN (1981) provides a statistical profile of the Academy's membership in the 18th century, albeit one that is somewhat too mathematically rigid. McCLELLAN (1985) sheds new light on the Academy's international relations and its place within the international organization of science at the time. BRIGGS offers an insightful study of the Academy's rather limited concern with technology and applied science in the *ancien régime*.

As part of their extirpation of *ancien régime* institutions, republicans in the National Convention suppressed the Academy of Science and other academies on 8 August 1793. Hahn is especially strong in tracing the demise of the old Academy and its revival in 1795 as the First Class of the Institut de France. OUTRAM examines the interregnum of the Terror and important continuities and discontinuities in the institutional history of the Academy from the point of view of the psychology of academicians in the turbulent months of 1793–95.

The 1992 volume by CROSLAND represents the first comprehensive study of the Academy in the 19th century, and it revises several cherished views. A former commonplace, for example, was that, with the growth and disciplinary specialization of science in the 19th century, the Academy became little more than a scientific hall of fame. Crosland, however, reveals the 19th-century Academy to have been of enormous influence and at the active center of contemporary French science and scientific research, and he documents how scientific life in and around a more democratic and discipline-oriented Academy orchestrated professional careers and a network of scientific institutions and appointments. The appearance in 1835 of the weekly *Comptes rendus* of the Academy and the elaboration of a system of prizes and grants thrust the institution to the forefront of French and world scientific production.

At the end of the 19th century the vitality of the Academy does seem to have declined in relation to other French scientific institutions and the rest of French science generally. Given the wealth of resources available to anyone approaching the history of the Academy of Sciences, the lack of a modern scholarly study of the Academy in the 20th century is all the more disappointing.

JAMES E. MCCLELLAN III

Accademia dei Lincei

Accademia (L') dei Lincei e la cultura europea nel XVII secolo: Manoscritti – Libri – Incisioni – Strumenti scientifici, catalogue of the exhibition organized by A.M. Capecchi *et al.*, Rome: Accademia Nazionale dei Lincei, 1992

Biagioli, Mario, "Knowledge, Freedom and Brotherly Love: Homosociality and the Accademia dei Lincei", *Configurations*, 3 (1995): 139–66

Clericuzio, Antonio and Silvia De Renzi, "Medicine, Alchemy and Natural Philosophy in the Early Accademia dei Lincei", in *Italian Academies of the Sixteenth Century*, edited by D.S. Chamber and F. Quiviger, London: Warburg Institute, 1995

Convegno celebrativo del IV centenario della nascita di Federico Cesi, Acquasparta 7–9 ottobre 1985, Rome: Accademia Nazionale dei Lincei, 1986

Gabrieli, Giuseppe, *Contributi alla storia dell'Accademia dei Lincei*, 2 vols, Rome: Accademia Nazionale dei Lincei, 1989

Gardair, Jean-Michel, "I Lincei: i soggetti, i luoghi, le attività", *Quaderni storici*, 48 (1981): 763–87

Olmi, Giuseppe, "In essercitio universale di contemplatione e prattica: Federico Cesi e l'Accademia dei Lincei", in his *L'inventario del mondo: Catalogazione della natura e luoghi del sapere nella prima età moderna*, Bologna: Il Mulino, 1992

Raimondi, Ezio, "Scienziati e viaggiatori", in *Storia della Letteratura Italiana*, vol. 5, edited by Emilio Cecchi and Natalino Sapegno, Milan: Garzanti, 1967

The foundation of the Accademia dei Lincei by the Roman Prince Federico Cesi in 1603, and its subsequent enrolment of Galileo Galilei in 1611, have a secure place in the history of science. For a long time, however, discussions of the Accademia have had a somewhat ritual character, a nationalist historiography celebrating it as the pioneering first "scientific" academy and a model for later institutions. The recent general reassessment of such categories as scientific revolution and more specific studies of courtly culture have made it possible to reconsider the Accademia and its intellectual project. But so far the only extended analysis we have is OLMI's article, while the Accademia's immense archive has not yet been exploited.

ACCADEMIA, the catalogue of an exhibition organized in Paris in 1991, is a useful introduction to the history of the Accademia, as it offers a close view of documents, books and other objects which are not easily available. Exhaustive notes and remarkable illustrations document the wide range of the Accademia's interests very well.

GABRIELI's book gathers together the numerous papers he wrote for various journals between the 1920s and the 1940s. These were the result of his valuable archival research and

were complemented by his publication in the 1940s of a large part of the correspondence of the Lincei. He concentrates primarily on the biographies and works of the members of the Accademia and these learned and meticulous profiles are still the starting point for research. His interpretation of the Accademia as a whole is, however, hagiographic: emphasising the role of the heroic scientist, Galileo Galilei, he builds for the Accademia the myth of a sudden turn from infatuation with late Renaissance natural philosophy and magic to the acquisition of the scientific method. In so doing, Gabrieli completely neglects crucial aspects of the activities of the Lincei, such as their medical and alchemical interests. These are the main subject of CLERICUZIO & DE RENZI's article. Focusing on the works of some of the Accademia's leading members, they show that an early interest in chemical and Paracelsian experimentation was by no means replaced by "more scientific" investigations. Rather, an updated knowledge of iatrochemistry, along with intense anatomical practice, remained an important feature of the medical activities and natural investigations of the numerous physicians among the Lincei.

In his still useful article, RAIMONDI analyses Cesi's intellectual project as part of the Prince's strong attack on the obsolete knowledge provided by the universities and endorsed in the courts. Cesi's violent antagonism to these sites of power led him to found a new and secluded institution, which with his utopian intentions should have been based on co-operation among scholars, direct observation of nature and the achievement of useful knowledge. Though this aim was only incompletely realised, Raimondi argues that the Lincei did achieve a major and far-reaching epistemological objective in developing a notion of accuracy and precision that was founded on their excellent use of scientific instruments like the microscope.

GARDAIR's paper is the first polemic challenge to the myth of national primacy. Basing his interpretation on statistical analysis, he points out that the Accademia actually organized rather few collective activities. By projecting backwards a stereotype of a "true" scientific institution, he argues that the Lincei were still trapped in courtly activities, and so developed only an amateurish approach to natural investigations. Although his statistics shed light on the social status and profiles of the Lincei, he fails to capture the distinctive features of the Accademia as an intellectual institution of court society.

One of the most balanced and well informed surveys of the Accademia is OLMI's article. He provides a thorough reading of the Accademia's still unpublished "Statute", and finds in the Lincei's commitment to a wide circulation of the results of its natural investigations one of the interesting novelties of its project. Furthermore, relying on the well-established political history of the Counter-Reformation, Olmi emphasises the complex relations between knowledge and political power in the first decades of the 17th century. Although Cesi declared that the price of the success of any innovative intellectual enterprise was complete neutrality on religious and political matters, almost all of the Lincei were in fact heavily involved in politics and diplomacy, especially on behalf of Galilei. But their considerable skills could not prevent the decline of the Accademia in the 1630s, when sudden political reversals unfavourably affected papal patronage.

More recently, BIAGIOLI has turned to gender history to make sense of the male bond and the rule of chastity that Cesi established for his Accademia. Undoubtedly, these were part of the military and aristocratic ethos he had inherited from his milieu, but, at the same time, brotherhood, freedom from sexual lust and seclusion ensured the Lincei the best conditions for the pursuit of their major epistemological aim, non-dogmatic knowledge and philosophical independence. Cesi's obsession with intellectual freedom can explain the main aporia of his project: the creation of an institution whose principal end was to put no constraint on its members. Moreover, this is the main feature of his Accademia, that, unlike later sites of natural research to which it has been compared inappropriately, it never became an articulated and regulated institution.

Although specific research has been done on other eminent members of the Accademia – such as Cassiano dal Pozzo, Giovanni Ciampoli and Johannes Faber – the life and intellectual background of its founder remains the principal topic for scholars. *CONVEGNO*, published for the centenary of Prince Cesi's birth, however, is a disappointing collection of papers of uneven quality. Among the best, Garin's article traces the late Renaissance philosophical sources of Cesi's plan, while Nicolò and Solina's contribution focuses on Cesi as a collector.

SILVIA DE RENZI

Accademia del Cimento

Altieri Biagi, Maria Luisa, "Lingua della scienza fra Sei e Settecento", in *Letteratura e scienza nella storia della cultura italiana*, edited by Vittore Branca, Palermo: Manfredi, 1978

Baldini, Ugo, "La scuola galileiana", in *Storia d'Italia*, edited by Gianni Micheli, Turin: Einaudi, 1980, 381–463

Biagioli, Mario, "Scientific Revolution, Social Bricolage, and Etiquette", in *The Scientific Revolution in National Context*, edited by Roy Porter and Mikulás Teich, Cambridge and New York: Cambridge University Press, 1992

Celebrazioni della Accademia del Cimento nel Tricentenario della Fondazione (Domus Galileiana, 19 June 1957), Pisa: Domus Galileiana, 1958

Galluzzi, Paolo, "L'Accademia del Cimento: 'gusti' del principe, filosofia e ideologia dell'esperimento", *Quaderni storici*, 16 (1981): 788–844

Middleton, W.E. Knowles, *The Experimenters: A Study of the Accademia del Cimento*, Baltimore: Johns Hopkins University Press, 1971

Poggi Salani, Teresa, Introduction to *Saggi di naturali esperienze*, by Lorenzo Magalotti, edited by Poggi Salani, Milan: Longanesi, 1976

Van Helden, Albert, "The Accademia del Cimento and Saturn's Ring", *Physis*, 15 (1973): 237–59

By the middle of the 17th century a group of natural philosophers, including Francesco Redi, Alfonso Borelli and Vincenzo Viviani, were in the habit of meeting in Florence at the court

of the Grand Duke Ferdinando and his brother Leopoldo. Although they never subscribed to a formal charter and had different views on nature, for a period they worked together and conducted a range of physical experiments. A selection of their experimental trials was published after their erratic meetings had ended, in a book entitled *Saggi di naturali esperienze* (1667).

Since the 18th century, scholars have considered the Accademia del Cimento the first institution devoted entirely to experimental science. Positivist historiography has read its life, and especially its supposedly premature end, as an example of the interference of the Catholic Church in scientific activities in 17th-century Italy. Moreover, the Cimento's strong commitment to experimental trials has been explained as a strategic move to avoid philosophical issues that, after the Galilei affair, could become matters of dangerous conflict. In the last 20 years, however, all these assumptions, including the myth of the Cimento as a "scientific institution", have been questioned as scholars have fundamentally reassessed the status of natural investigations after Galilei's trial.

The principal aim of CELEBRAZIONI DELLA ACCADEMIA DEL CIMENTO is to celebrate the contributions made by members of the Accademia to various scientific fields. The most useful aspects of this work are the analytical description of archival material by Procissi, and the chapter by Righini Bonelli on the scientific apparatus owned and used by the Accademia.

The only book-length study on the Cimento is by MIDDLETON, who also presents a modern English translation of the *Saggi di naturali esperienze* and a valuable discussion of unpublished reports of the Accademia's experiments. His vast knowledge of archival sources makes this a detailed and still useful study. However, the account is largely descriptive, and Middleton does not really make the most of the rich material he has unearthed. This is clear, for instance, in the central chapter on the *Saggi*, in which he reconstructs their seemingly interminable editing and compares various extant drafts. Nevertheless, the only conclusion he offers is that the structure of the book clearly displays the Cimento's strong anti-Aristotelian bent, which, unfortunately, the Accademia could not openly state. Again, while Middleton acknowledges Prince Leopoldo's importance in establishing the Accademia, he does not tell us much about his intellectual background or his projects. On the whole, Middleton's evaluation is ambivalent: he admires the ingenuity of the experiments performed in the Accademia, but compares it unfavourably to other scientific institutions, especially the Royal Society. He seems to believe that the latter contributed much more to science.

Among the investigations not published in the *Saggi*, Middleton points to the usually neglected astronomical experiments carried out by the Cimento. Emphasising their importance to its history, VAN HELDEN's paper reconstructs the role of the astronomical models built by the Accademia in the long controversy between the astronomers Huygens and Divini about the rings of Saturn. To Prince Leopoldo's great embarrassment, both had dedicated their work to him and expected his authoritative approval. Taking the whole episode as an example of 17th-century intellectual negotiations, Van Helden focuses mainly on the Cimento's mastery of experimental technique in testing both hypotheses. He also underscores the impartiality ostentatiously shown by Leopoldo until the Accademia obtained definitive evidence in favour of Huygens's work.

BALDINI's account of the Cimento is a section of his sweeping, but not very reader-friendly, article on the reworking of Galilei's heritage in the second half of the 17th century. To counteract the positivist dogma on the Church's negative role, he suggests that more "internal" reasons, such as an inadequate development of mathematics, were responsible for the decline of Italian science. But, since he is by no means an internalist historian, Baldini frames this intellectual crisis within the stagnating Italian economy and the lack of a dynamic bourgeoisie, with the consequent low demand for mathematical and technical skills. Therefore, while he fully acknowledges the importance of princely patronage in the laboratory activities of the Cimento, he believes that in the long run this typical courtly feature was a restraining factor in the history of Italian scientific investigations.

The most convincing and influential revision of the old historiography is GALLUZZI's paper. He stresses that princely patronage was not just an element in the history of this supposedly scientific enterprise, but rather the only reason for its existence. Far from being a scientific institution based on collaboration among researchers, the Cimento was one of the greatest successes in the cultural policy of the Medici. Prince Leopoldo's crucial role in setting the experimental agenda of the Accademia and in strongly promoting the publication of the *Saggi* are the strongest evidence for Galluzzi's thesis. Galluzzi further shows that the violent contrasts among members of the Cimento, both on relevant philosophical issues and on their careers, were cleverly hidden by the Prince. Through the Cimento he succeeded in building a long-lasting myth of his patronage and of neutral and consensual experimental knowledge. Galluzzi, however, is keen to emphasise that, like Borelli, not all members of the Accademia shared the Prince's conciliatory view and resented the interference of court patronage.

BIAGIOLI owes much to Galluzzi's thesis, but he develops a stronger sociological approach. His contribution is a section of a more general article in which, by comparing various national contexts in the late 17th century, he argues for the role of political power and court culture in structuring argumentative styles and scientific protocols. Thus, he understands the Cimento's celebrated empiricism as nothing but the outcome of a strict courtly rule that required princes to avoid harsh and status-tainting intellectual disputes. Only a science based on experimental trials and emptied of philosophical speculations allowed Leopoldo to take part in natural investigations and to be an authoritative patron. Biagioli invokes his status to make sense both of the institutional nature of the Accademia – a private rather than a public space – and of the content of its natural investigations. This is an interesting thesis, but since it is largely focused on Leopoldo, it is disappointing that the Prince remains a silhouette, and that almost nothing is said about his education, intellectual profile and political career between Florence and Rome.

In the 1970s scholars such as ALTIERI BIAGI drew attention to the making of a scientific prose in 17th-century Italy. The language used by Count Magalotti, analysed by POGGI SALANI, in writing the *Saggi*, and by other members of the

Cimento such as Redi, represented an important step in this direction. Now that courtly rhetoric and etiquette are at the centre of early modernists' concerns, such linguistic and literary researches may attract renewed interest.

SILVIA DE RENZI

Accountability

Ashworth, William J., "The Calculating Eye: Baily, Herschel, Babbage and the Business of Astronomy", *British Journal of the History of Science*, 27 (1994): 409–41

Kula, Witold, *Measures and Men*, translated by R. Szreter, Princeton, New Jersey: Princeton University Press, 1986

Lynch, Michael, *Scientific Practice and Ordinary Action: Ethnomethodology and Social Studies of Science*, Cambridge and New York: Cambridge University Press, 1993

Porter, Theodore M., *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, Princeton, New Jersey: Princeton University Press, 1995

Power, Michael (ed.), *Accounting and Science: Natural Inquiry and Commercial Reason*, Cambridge and New York: Cambridge University Press, 1996

Shapin, Steven, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, Chicago: University Press of Chicago, 1994

Accountability is a concept primarily associated with the idea of making the organisation and decision making apparatus of a government or public serving body answerable to the public, or a joint stock company responsible to its shareholders. At a time when there is such widespread mistrust of the institutions that combine to constitute what we loosely refer to as the State, the word accountability seems hardly to be out of the news. A form of accountability is seen as the means by which to preserve the integrity of (especially expert) institutions.

A useful starting point is a historical period when accountability in the above sense did not exist. During the 17th century, as SHAPIN has described, agreement about what constituted a piece of knowledge was reached through unspecified processes based on a set of social conventions. Veracity was a product of virtue defined by a gentlemanly code that gained its sense by a flourishing courtesy literature. The most important social characteristic was to be independent and therefore to seemingly have no reason to lie. Testimony lay at the core of economic truth-telling and was therefore implicit in relations of trust. An individual or an organisation was called to account not through a strict set of rules and set of ledger books, but via an unspecified code of economic behaviour played out in mainly face-to-face encounters.

Accountability was a term that emerged from the informational deluge of the late 18th century which accompanied the gradual forging of the notion of "the public". At the same time it witnessed the decline of genteel virtue and the *ancien régime*, with a movement towards specialisation and expert institutions. The notion of making people accountable for their actions or claims also finds an analogy in weights and measures. The work of KULA demonstrates that prior to the metric system, units of measurement referring to concrete objects such as the finger, foot and ell (elbow) were in everyday use. They had no abstract, standardized denomination. In short, accounting for the weight or measure of a commodity was a qualitative process that varied from region to region (and indeed within regions), and was suited to small communities. Kula argues that with the growth of the power of the state, increased commerce and expanding markets during the second half of the 18th century, weights and measures were increasingly made accountable to a standard meaning. The crucial impetus was the metrification of weights and measures in France, and its establishment in Europe during the 19th century. Metrological equality required measures to be independent of man and therefore seemingly morally neutral; this simultaneously required the equality of man before the law and the alienation of the commodity.

The late 18th-century legal philosopher Jeremy Bentham made accountability a cornerstone of his vast writings; the political radical Thomas Paine made it a key part of his pleas for social reform; and the stockbroker, member of parliament and political economist David Ricardo consistently pressured the government to make the Bank of England more accountable to parliament. Simultaneously, movements in science sought to make scientific claims more accountable. For example, ASHWORTH looks at the drive in 1820s London to police speculation in science and finance alike and to make both activities visibly accountable. Such a development required standardized tools (calculating tables and experimental apparatus) and indeed the idea of a generalized scientific method. Ideally, as Jeremy Bentham sought, the whole history of decision-making should be rendered visible and therefore accountable.

The contributors to POWER examine the function and character of economic calculation within science. They claim that to understand science we must examine the diverse array of expert scientific communities, the importance of lobbying for funds (and the bodies in charge of these funds), and the demands for public accountability. Power claims that science is now made accountable in economic terms through the use of accountancy, and there has been a shift from preoccupation with the scientificity of accounts to the financial accountability of science. In this sense science now has to be put into quantitative terms before it can be made accountable. Consequently, to obtain a better understanding of science we should look more closely at the practice of economic calculation. To do this we should make accountancy itself visible.

Numbers are the language we now generally associate with accountability. PORTER has traced the rise of trust in numbers in both science and politics to a desire to make decisions accountable – that is, literally to depersonalize the whole process and thus shift the onus to one not seemingly based on the interests of a particular social group. It was the insecure realm of social administration and policy, he argues, which introduced numerical objectivity (rather than the natural sciences). Moreover, it was propagated by those placed in a relative position of weakness within large bureaucracies – this can be seen particularly in the US during the 20th century. In short, accountability through standardized rules and impersonal numbers is a product of those primarily in a weak position. This formalization seemingly expels the need for personal

trust. It is central, Porter argues, to a more open and therefore accountable society. In this sense trust in numbers is a fundamental axis in the functioning of a democratic society.

However, it could be argued that this process of depersonalization still shields the particular social interests hiding behind numbers. For SHAPIN, face-to-face contact and a more primordial form of trust remain necessities even to those practising science in modern democratic countries; and equally, this numerical depersonalized process continues to depend for its validity on an equally social and moral code of truth-telling. Therefore the important issues are: who deems what numbers are meaningful, and who is qualified to produce them? To understand the numbers you have to understand the people who produce them, and to understand what it is to be accountable you have to understand who legislates for this process.

Another way of looking at accountability within a scientific context is given to us by LYNCH. To appreciate the ethnomethodological approach we now have to shift our attention from the encompassing themes offered above, and travel to the more local and mundane. For Lynch and the ethnomethodologists there is no foundational, structuralist or materialist framework in which accountability should be situated. Rather, it is how the order and reason of scientific activities make themselves accountable within the setting in which it occurs. Accountability here does not retain some common features, but is simply concerned with observing how those involved in scientific practice make their activities accountable. Anyone who is a competent participant in the activity under scrutiny will recognize it as orderly, ordinary, and observable. Hence, through a number of ethnomethodological tools, those participants under examination can be held to account for their actions. Accountability, in this sense, is making the routine, taken-for-granted activities visible and recognizable (accountable). What it is to be accountable and give an account of the activity is reflexively embedded within the activity.

WILLIAM J. ASHWORTH

See also Accountancy; Quantification

Accountancy

Ashworth, William J., "The Calculating Eye: Baily, Herschel, Babbage and the Business of Astronomy", *British Journal of History of Science*, 27 (1994): 409–41

Babbage, Charles, *On the Economy of Machinery and Manufactures*, Philadelphia: Carey and Lea, 1832; London: 1832; 3rd edition, London: Knight, 1833

Hopwood, Anthony and Peter Miller (eds), *Accounting as Social and Institutional Practice*, Cambridge and New York: Cambridge University Press, 1994

Lowood, Henry, "The Calculating Forester: Quantification, Cameral Science and the Emergence of Scientific Forestry Management in Germany", in *The Quantifying Spirit in the 18th Century*, edited by Tore Frängsmyr, J.L. Heilbron and Robin E. Rider, Berkeley: University of California Press, 1990

Mumford, M.J. and K.V. Peasnell (eds), *Philosophical Perspectives on Accounting: Essays in Honour of Edward Stamp*, London and New York: Routledge, 1993

Noble, David, *America by Design: Science, Technology and the Rise of Corporate Capitalism*, New York: Knopf, 1977; Oxford: Oxford University Press, 1979

Porter, Theodore M., *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, Princeton, New Jersey: Princeton University Press, 1995

Power, Michael (ed.), *Accounting and Science: Natural Inquiry and Commercial Reason*, Cambridge and New York: Cambridge University Press, 1996

Sterling, Robert, *Toward a Science of Accounting*, Houston, Texas: Scholars Book, 1979

Swetz, Frank, *Capitalism and Arithmetic: The New Math of the 15th Century*, La Salle, Illinois: Open Court, 1987

Taylor, Frederick, *The Principles of Scientific Management*, New York: Harper, 1911

At first glance the history of science and the history of accountancy have little to do with each other. "Heroic" conceptions of scientific activity have tended to exclude the influence of practices such as accounting, because they threaten to make either science too mundane or accounting "too interesting". However, increasing attention to the laboratory context of scientific activity, and the widespread recognition that science and society are a "seamless web", have created a new intellectual agenda that spans formerly distinct fields of inquiry.

The precise form of entanglement between scientific and accounting practice has only recently become an explicit object of interest, and the literature is far from extensive or well-developed. Broadly speaking, a convergence of research interests across the sociology of science, history of science, and accounting has occurred around three relatively discrete themes: the claims of accounting to be a science; accounting as a model of administrative objectivity; and the impact of accounting on science.

As far as the first theme is concerned, accountancy, like many other disciplines, has experienced "scientistic" longings, searching for legitimate foundations in a particular, and now largely discredited, model of natural science. This programme is not as implausible as it sounds, since systematic accounting techniques emerged in conjunction with developments in arithmetic. SWETZ analyses the cultural background of the *Treviso Arithmetic* and the commercial demands that drove arithmetical innovation, particularly in 14th- and 15th-century Italy where double-entry bookkeeping became well established and was famously codified by Luca Pacioli.

More recently, accounting scholars such as STERLING have pursued the dream of reconnecting accounting to its nobler "scientific" origins by transforming it into a science. MUMFORD & PEASNELL contains many essays that extend and criticise this dream although, apart from a few "realists" of economic measurement, it has not gained mass support, even though the rhetoric of science has proved convenient from time to time. Despite Sombart's bold claim that double-entry bookkeeping was born of the same spirit as the systems of Galileo and Newton, accounting researchers in the late 20th century aspire to be social scientists themselves and are less concerned about whether accounting is, or could be, regarded as scientific.

PORTER has argued that the scientistic aspirations of Sterling and others should not be dismissed out of hand. He

claims that there is much to be learned about science from the "objectivity" debates of other disciplines. In particular, the claimed administrative objectivity and neutrality of accounting typify an important dimension of the social "trust in numbers". Practices of quantification in general, and of accounting in particular, crystallize social demands for forms of procedural fairness. Indeed, the imperatives of administrative consensus have almost become indifferent to the epistemological problem of whether accounting can give an accurate representation of the world. Accordingly, Porter's frame of reference is a history of objectivity in which science is one practice among many.

Despite Porter's rehabilitation of accounting as a (philosophically) interesting component of the history of objectivity, the economic and material basis of scientific activity is not a new theme. ASHWORTH explores the reciprocal relations between accountancy and astronomy in 19th-century Britain. This is not simply a question of business as a context for science, but of the co-production of key concepts in each field. LOWOOD makes these conceptual exchanges visible within the context of German forestry management, and in BABBAGE's *On the Economy of Machinery and Manufacturers* (1832) ideas of rational factory management correspond to those of a natural world system. Hence, notions of economy, calculation, balance, and precision have played decisive roles in the formation of both business and scientific practice, in which there are constant exchanges between intellectual and financial capital.

NOBLE shows how elements of Babbage's ideas were put into practice by TAYLOR some years later in North America. Taylor pioneered rational economic procedures in the form of cost accounting and statistical control, which constituted a re-engineering of the workplace. Critical analyses of Taylorism and other accounting-based reforms have revealed the way accounting is both constructed by social and economic demands and constitutive of its environment. The essays in HOPWOOD & MILLER are paradigmatic of this constructivist view of accounting: accounting techniques make organisations and individuals "visible" and "knowable" in economic terms. Financial statements, cash budgets and standard costing techniques are, like laboratory instruments, all ways of "representing and intervening".

These themes in the sociology of accounting meet the sociology of science in a number of the essays in POWER. This brings us full circle, from scientistic attempts to reform accounting to a consideration of the accounting-based reforms of public science that have taken place in many countries since the mid-1980s. Although there is no suggestion in these essays that public science has not always been shaped and made accountable in various ways to peers, patrons and the public, the financial accountability of science has intensified in recent years. And, despite earlier studies of the corporate laboratory within business history, it can be no accident that the "economics of science" is an emerging research programme in the 1990s, at a time when laboratory practice is itself being challenged and transformed by the need to give a financial account of itself. It is as if the distinction between factories and laboratories has become blurred, and the power of accounting techniques to represent scientific practice within policy contexts is transforming ways of thinking and speaking about scientific practice. Hence, although the position of accountancy research within the history of science has been at best marginal, it is likely to assume greater importance in the future, as accountancy and scientific practices increasingly overlap.

MICHAEL POWER

See also Accountability; Quantification

Acoustics

Fletcher, Neville H. and Thomas D. Rossing, *The Physics of Musical Instruments*, New York: Springer, 1991

Hunt, Frederick Vinton, *Electroacoustics*, Cambridge, Massachusetts: Harvard University Press, 1954

Hunt, Frederick Vinton, *Origins in Acoustics: The Science of Sound from Antiquity to the Age of Newton*, New Haven, Connecticut: Yale University Press, 1978

Lindsay, R. Bruce (ed.), *Acoustics: Historical and Philosophical Development*, Stroudsburg, Pennsylvania: Dowden Hutchinson and Ross, 1971

Maley, V. Carlton, *The Theory of Beats and Combination Tones, 1700–1863*, New York: Garland, 1990

Palisca, C.V., "Scientific Empiricism in Musical Thought", in *Seventeenth Century Science and the Arts*, edited by Hedley Howell Rhys, Princeton, New Jersey: Princeton University Press, 1961

Rayleigh, Lord (John William Strutt), *The Theory of Sound*, 2 vols, London: Macmillan, 1877–78; reprinted, New York: Dover, 1945

Wood, Alexander, *The Physics of Music*, London: Methuen, 1945; 7th edition, revised by J.M. Bowsher, London: Chapman and Hall, and New York: Wiley, 1975

Historical literature about acoustics is, unfortunately, quite sparse. Acoustics is a "cross-roads" subject; its historical development can only be understood within the context of its relation to certain other sciences and arts, and this complexity perhaps explains the paucity of the literature. Nevertheless, the books and articles presented here are the most accurate and comprehensive currently available, and will provide a complete, if rather one-dimensional, history of the subject.

The best place to start is HUNT (1978). Unfortunately, the work is unfinished, and only the chapters that present the history of acoustics from ancient times to the 17th century are published in a complete form. The book's great strengths, however, are its comprehensive presentation of the scientific background of each era investigated and the stress it lays on the importance of the interrelations between acoustics and other sciences. In particular, it gives a good picture of developments in acoustics in association with developments in music.

Research in acoustics in the 16th and 17th centuries is the subject of PALISCA, who discusses the development of acoustics against the background of 17th-century empiricism and the scientific revolution. Palisca makes effective use of the fact that the evolution of acoustics is closely related to that of the theory of music and of the construction of musical instruments, in order to demonstrate the shift to empiricism that took place during this period.

MALEY looks at the development of ideas and beliefs concerning the combination tones, a subject that has been at the centre of acoustical research for at least three centuries, and which gives a useful picture of the progression of "acoustics" from merely a servant of music to a physical subject in its own right. Maley provides a clear picture of the ideas of the time (1700–1863), and lucidly describes the underlying physics of the problem.

HUNT (1954) contains a 91-page historical introduction to the problem of transducers and telephony, from the early 19th century through to the first decades of the 20th century. The inventions of the telegraph and telephone are covered in detail, and there is also an excellent discussion on the development of the field of electroacoustics (including a section on underwater acoustics and sonar). The references are extensive and together offer a complete guide to this particular subject.

WOOD covers in full the problem of the physics of music. The book assumes a minimal knowledge of physics, and so can be enjoyed by all those interested in the subject, whatever their background. Aside from this, Wood gives a great deal of historical information about almost everything related to the acoustics of music, including combination tones and temperament, musical instruments and the basic principles of musical theatre architecture. Unfortunately the book suffers from a lack of references to the original publications, but other books referenced by Wood would give this information.

FLETCHER & ROSSING's aim is similar to Wood's, but their book requires a greater knowledge of physics to be useful. Moreover, the historical elements are few, and mainly concern the physics of vibrations and the histories of individual instruments. The reference section lists other books giving the history of the development of different instruments.

LINDSAY has collected 39 original articles on subjects related to acoustics, ranging from those from antiquity (Aristotle and Vitruvius) to those from the end of the 19th century (Rayleigh). Matters discussed include acoustics in general, propagation of sound (in air or any other medium), the acoustics of theatres and the mathematics of acoustics. Some of the articles included were translated by Lindsay from their original language (Latin, German or French) for the first time. Lindsay's introduction also gives a short summary of the history of acoustics with useful references.

Finally, RAYLEIGH's *The Theory of Sound* should be included because the Dover edition has a useful introduction by R.B. Lindsay, which gives a short summary of the history of acoustics. Moreover, even though Rayleigh's book is not in fact a history of sound, the lack of a book in the literature that includes the original references for the mathematics of acoustics (vibration of strings, bars, plates, and membranes etc.) makes its inclusion something of a necessity.

BASILEIOS DROLIAS

See also Music and Science: Antiquity to 1700; Music and Science: since 1700

Acupuncture

Farquhar, Judith, *Knowing Practice: The Clinical Encounter of Chinese Medicine*, Boulder, Colorado: Westview Press, 1994

Geoffroy, Daniel, *L'Acupuncture en France au XIXe siècle*, Paris: Maisonneuve, 1986

Kuriyama, Shigehisa, "Interpreting the History of Bloodletting", *Journal of the History of Medicine and Allied Sciences*, 50 (1995): 11–46

Lu Gwei-Djen and Joseph Needham, *Celestial Lancets: A History and Rationale of Acupuncture and Moxa*, Cambridge and New York: Cambridge University Press, 1980

Saks, Mike, *Professions and the Public Interest: Medical Power, Altruism and Alternative Medicine*, London and New York: Routledge, 1995

Unschuld, Paul U., *Medicine in China: A History of Ideas*, Berkeley: University of California Press, 1985 (original edition, 1980)

As with many issues in Asian science and medicine, Joseph Needham's vast series *Science and Civilization in China* is the main point of departure for examinations of acupuncture, and the volume by LU & NEEDHAM is a separately published section of that series. As the title implies, this work is designed to supply the needs of two distinct groups of readers, the historians (whether of medicine, Chinese science, or the interchange between East and West) and those seeking a theoretical understanding of acupuncture medicine. Neither it, nor any of the other books in this entry, is intended as a practical guide to using the treatment. Lu & Needham begin by defining the body as it has been theorized in classical Chinese acupuncture texts, and then describe the growth of the therapy as a specialized medical practice. After an extensive discussion of "the possible physiological interpretations which look like giving it a rationale in terms of modern science", the authors examine acupuncture's reception and history in Asia and Europe. They conclude with an analysis of acupuncture's influence as a system of therapy. Ironically, considering their ample critique of Western medicine before the 20th century, *Celestial Lancets* is somewhat hampered by its authors' uncritical acceptance of the truth status and authority of Western scientific medicine. None the less, it remains a vital resource in studying acupuncture's historical development and diffusion, and an excellent starting point for those who wish to understand the traditions and theories underlying the therapeutic use of the needle in Chinese medicine.

UNSCHULD's work continues this tradition of Chinese medical scholarship, adding a strong interpretative and theoretical framework and a more critical stance on the value of scientific medicine. The book treats Chinese medicine as a whole, with acupuncture as one node within a wider network of treatments and ideologies of the body and disease. Unschuld argues that a complex culture inevitably produces a complex and often contradictory set of medical systems; these systems are characterized by both stable paradigmatic cores and "soft coatings", susceptible to the changing currents of their sociopolitical milieu. To make visible the ways in which change and diversity emerge within health care, Unschuld proposes a four-

pronged approach, entailing chronological, linguistic, structural and socio-political analyses of medical systems. In the case of acupuncture, Unschuld illustrates the changing rationales offered for the treatment through the writings of individual practitioners at different periods in China's history. These individual voices are among the best features of the book, which draws its sources from the pre-history of China to its present.

Although these first works focus on acupuncture's Chinese roots and history, the therapy has been examined from several other perspectives. Its history in Europe and North America has been studied, though in less depth than its history in China. For example, GEOFFROY details the 17th- and 18th-century transmission of acupuncture to Europe, and its subsequent role in 19th-century French medical culture. The text is rich in contemporary French reports of needling, and describes both medical and popular responses to acupuncture. However, the author offers no explanation for the century-long delay between the initial transmission of information about the therapy and acupuncture's eventual adoption by the medical community, or for the fluctuating popularity of the technique in 19th-century France.

Acupuncture has also been used as a lens through which to examine alternative medicine, modalities of the clinical encounter, and the behaviors and motivations of professional groups. SAKS offers a survey of the British medical profession's historical and contemporary responses to acupuncture, documenting a persistent "climate of rejection", based not on the relative therapeutic merits of the needle but on the economic and political exigencies of the medical profession in Britain. Here, acupuncture acts as the stage on which Saks demonstrates his new method of assessing the motivations of professional groups; however, this approach fails to acknowledge the cultural attributes of acupuncture, and their effect on the response of the medical community and clientele. Moreover, in focusing so intently on the power of the medical profession to create this "climate of rejection", Saks falls into the trap of seeking a single explanation for a highly complex phenomenon. Nevertheless, the book begins to examine the long-term pattern of professional response to acupuncture in the West, and offers an example of the way in which acupuncture can act as a window through which to observe larger medical and cultural systems.

KURIYAMA's article also uses acupuncture as a means of investigating a broader set of issues. However, he shifts from studying acupuncture either alone or contrasted with modern Western medicine to a comparative analysis of the early histories of acupuncture and phlebotomy. The two therapies emerged synchronously and were initially quite similar, despite their geographical separation. Kuriyama uses comparisons between their diverging paths to illuminate underlying conceptual differences between Greek and Chinese ideas of health and disease. This article illustrates a new way of studying acupuncture and Chinese medicine; the rigid wall between analyses of Eastern and Western medicine is breaking down, and it is being replaced by historical work that looks, not at one side alone, but at each side as a guide to interpreting and understanding the other.

Finally, FARQUHAR, although not focusing solely on acupuncture, offers a vivid picture of the contemporary practice of Chinese medicine. Embedded within a broad ethnographic portrait are glimpses of acupuncture within its native context, practised as a living, and even as a mundane therapy. Farquhar examines Chinese medical praxis through its theory, institutions, practitioners and cases, but her emphasis is on the persistent particularity of diagnosis and on the skilled knowledge that is displayed and valued by practitioners of traditional Chinese medicine. Farquhar's text is certainly not designed to provide basic information about acupuncture or historical facts about needling; nevertheless, it canvasses and interrogates day-to-day clinical medicine in China and provides a useful foil to historical works on acupuncture.

ROBERTA E. BIVINS

See also China: medicine; Complementary Medicine

Adler, Alfred 1870–1937

Austrian psychologist

Adler, Kurt A. and Danica Deutsch (eds), *Essays in Individual Psychology: Contemporary Applications of Alfred Adler's Theories*, New York: Grove Press, and London: Evergreen Books, 1959

Bruder-Bezzel, Almuth, *Alfred Adler: Die Entstehungsgeschichte einer Theorie im historischen Milieu Wiens*, Göttingen: Vandenhoeck & Ruprecht, 1983

Hoffman, Edward, *The Drive for Self: Alfred Adler and the Founding of Individual Psychology*, Reading, Masachusetts: Addison-Wesley, 1994

Mosak, Harold H., "Adlerian Psychotherapy", in *Current Psychotherapies*, edited by Raymond J. Corsini and Danny Wedding, 4th edition, Ithaca, Illinois: Peacock, 1989

Sperber, Manès, *Masks of Loneliness: Alfred Adler in Perspective*, New York: Macmillan, 1974

Stepansky, Paul E., *In Freud's Shadow: Adler in Context*, Hillsdale, New Jersey: Analytic Press, 1983

Sweeney, Thomas J., *Adlerian Counseling*, Boston: Houghton Mifflin, 1975; 2nd edition, Muncie, Indiana: Accelerated Development, 1981

The literature on Alfred Adler tends to be determined by Adler's opposition to Sigmund Freud; even where it is biographical, much emphasis is put on the development of the Adlerian alternative in psychoanalysis, and the fact that both Adler and Freud were Viennese has prompted much of the literature to analyse Adler within the context of his home city.

Adler, according to SWEENEY in his overview account, began his career as an ophthalmologist in 1898, switched to general practice and then to neurology. He published his first psychological paper in 1904, and from 1907 to 1937 he became a catalyst in the field of psychotherapy. However, his name is not as well known as that of Freud, perhaps because he focused on teaching, rather than on publishing and promoting his theories.

Adler's idea of community was forged in his early years as a street urchin in the outskirts of Vienna. Even though he was Jewish, he grew up within a Christian community; Vienna at

the time was anti-Semitic, and Freud, his contemporary who also lived in Vienna, had a very different childhood experience. SPERBER suggests that Adler's conversion from Judaism to Protestantism was not the result of a change in belief, but of a desire to escape the Viennese scorn of Jews, and he eventually became an atheist. Freud and Adler developed their theories at about the same time, but came to very different conclusions; in a very readable format, HOFFMAN outlines the effects of early developmental impressions on Adler, and traces his professional development, his relationship with Freud and the eventual breakdown of their relationship.

Sperber also examines the societal norms of Vienna and their influence on the development of the field of psychotherapy, and explains how Adler formulated his concepts of the unconscious, dream interpretation, repression, personality types, sexuality, social organization and authority, in contrast, and sometimes in opposition, to Freud's positions and attitudes. Sweeney provides an overview of Adler's theories, grouping his basic concepts under the following headings – socio, teleo, development, family constellation, life tasks, emotions, values, and validation.

ADLER & DEUTSCH have compiled papers that support and define the concepts and theories originally conceived by Alfred Adler. Theories of personality through to therapeutic interventions are presented, illustrated, and expounded on, showing how his basic theories of social interest, lifestyle, family constellation, and so on, can be applied to therapeutic situations.

Sweeney explains Adler's differing views on counselling and psychotherapy, with attitudes toward lifestyle and behavior indicated as determining factors. MOSAK provides an overview of the basic theory of Adlerian psychotherapy, comparing it to other systems and giving the historical background to its development. He includes a theory of personality and defines concepts such as lifestyle, social inferiority and the broader context of a therapeutic relationship. For the practitioner, helpful techniques are described, and case studies illustrate how social interactions can be addressed within a therapeutic relationship.

Sperber touches on Adler's theories of hysteria and psychosomatic illness, and promotes Adler's theory of learned behavior. Adler believed that individuality is shaped by one's environment and that traits are learned. He observed developmental behavior and formulated his theory of inferiority on a child's need for language, on physical and social development, and on the awareness of one's own consciousness. Adler expounds on the development of the subconscious in conjunction with his theory of repression.

Sweeney takes a more specific look at Adler's views on child guidance, counselling, consultation and group procedures. Adler saw child guidance as intertwined with life tasks; his theory is based on the influence of others on the child, and a child's need for social contact, and considers a child's behavior, whether disruptive or not, as goal-based with natural or logical consequences.

Hoffman traces how, later in life, Adler lectured throughout the US on the subject of society and the personality; through these lectures, he helped the general populace to define anxieties centered on social issues. Of interest is his discussion of personality and its draw. Hoffman suggests, however, that Adler was often sought out as a lecturer because of his personality, rather than his tenets.

STEPANSKY examines Adler's later system of Individual Psychology against the backdrop of the Freudian years, and argues that the split between Freud and Adler should not dominate the critical assessment. Stepansky aims to evaluate Adler's status as educator and psychiatrist by placing him within a wider cultural and intellectual matrix.

BRUDER-BEZZEL goes even further in the attempt to contextualize Adler. She places Adler within the *zeitgeist* of his generation in Vienna, arguing that scientists and artists were moving away from causal–scientific thought towards holism, in which the driven psyche is replaced by the conception of the individual as an active subject. Within this, Bruder-Bezzel argues, Adler exposes masculinity as a posture, masking an inferiority complex born out of a fear of social degradation.

SALLY S. GRAHAM

See also Freud; Psychoanalysis: conceptual; Psychoanalysis: institutional

Aether

Cantor, Geoffrey and Michael J.S. Hodge (eds), *Conceptions of Ether: Studies in the History of Ether Theories, 1740–1900*, Cambridge and New York: Cambridge University Press, 1981

Doran, Barbara Giusti, "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): 133–260

Hunt, Bruce J., *The Maxwellians*, Ithaca, New York: Cornell University Press, 1991

Schaffner, Kenneth F., *Nineteenth-Century Aether Theories*, Oxford and New York: Pergamon Press, 1972

Schofield, Robert E., *Mechanism and Materialism: British Natural Philosophy in an Age of Reason*, Princeton, New Jersey: Princeton University Press, 1970

Swenson, Loyd S., *The Ethereal Aether: A History of the Michelson–Morley–Miller Aether-Drift Experiments, 1880–1930*, Austin: University of Texas Press, 1972

Whittaker, Edmund T., *A History of the Theories of Aether and Electricity from the Age of Descartes to the Close of the Nineteenth Century*, London and New York: Longmans Green, 1910

Wilson, David B., "The Thought of Late Victorian Physicists: Oliver Lodge's Ethereal Body", *Victorian Studies*, 15 (1971): 29–48

Wynne, Brian, "Physics and Psychics: Science, Symbolic Action, and Social Control in Late Victorian England", in *Natural Order: Historical Studies of Scientific Culture*, edited by Barry Barnes and Steven Shapin, Beverley Hills, California: Sage, 1979

Most early histories of the aether present a technical discussion of this unseen medium, rather than an examination of the broader intellectual contexts within which the concept of the aether was constructed. In recent years, historians have shown

much more interest in how the aether performed specific functions within particular intellectual and cultural settings, and have developed historiographies appropriate to different phases of aether history.

The Cambridge mathematician Edmund WHITTAKER produced one of the first comprehensive surveys of the development of the concept of the aether from the earliest times, through the ideas of Newton and the problems of aberration, to the great 19th-century theories of Augustin Jean Fresnel, Augustin Cauchy, Louis MacCullagh, George Gabriel Stokes and William Thomson. He is concerned solely with the technical development of the aether, and makes free and anachronistic use of vector calculus notation throughout his discussion: the latter may benefit science students, but it effaces important historical connections between Victorian mathematical language and the mechanical models that informed them.

SCHAFFNER's short technical survey includes readings from primary sources and is aimed at science students interested in the history of science. The author concentrates exclusively on Fresnel's optical aether, the elastic solid aethers of George Green and MacCullagh, and the electromagnetic aethers of George Francis FitzGerald, Joseph Larmor and Hendrik Antoon Lorentz. Despite his cursory treatment of Michael Faraday and James Clerk Maxwell, the author succeeds in depicting a continuous 19th-century project to weld optical, mechanical, and electromagnetic aethers. This is the best place to begin grappling with the mathematical foundations of important 19th-century aether theories.

SCHOFIELD examines the effects of Newton's legacy on 18th-century aether concepts in physics, chemistry and physiology, and demonstrates the rich material available for 18th-century aether scholarship. He characterises the work of early Newtonians as "mechanists", who primarily used Newton's *Principia* to explain natural phenomena in terms of material particles acting under discoverable force laws. By 1740, a second generation of Newtonians, the "materialists", rejected this tradition and used Newton's *Opticks* to interpret phenomena such as heat and electricity in terms of a Newtonian imponderable material aether. The author's rigid distinctions between "mechanism" and "materialism", and between "force" and "imponderables", have been severely criticised: for instance, Newton and his readers did not recognise the distinction between aethers and forces, but regarded the aether itself as the agency of repulsive forces.

DORAN's lucid technical prose complements Schaffner's mathematical approach. She makes William Thomson a pivotal figure in the Victorian demechanisation of the aether, from atoms in a void acting at a distance to a non-material, continuous electromagnetic field whose dynamical structures produce discrete material atoms. Thomson's 1856 vortex-atom theory of matter "spawned an entire tradition of aether and matter based on the continuous nonmaterial plenum", and Faraday's crucial conversion to field theory, and Maxwell and Larmor's speculations on aether and matter, owed much to Thomson's thinking. In this account, aethers were constructed to solve internal problems in optics and electromagnetism rather than to express wider intellectual and metaphysical concerns.

Physicists and historians have typically cited the celebrated Michelson–Morley experiments of 1880 and 1887 as definitive evidence against the existence of a stagnant luminiferous aether. SWENSON insists, rather unconvincingly, that the experiments were not designed to search for an aether, but were originally intended to study the behaviour of light through moving media. This "social history" stresses the personalities and the vicissitudes of experiments, and charts the decline of the aether through statistical analysis. The experiment on the aether, he concludes, "derived its importance far more from what it suggested than from what it imposed".

WILSON uses Oliver Lodge – one of the great Victorian aether architects – to discuss the religious and metaphysical functions of the aether. He argues that Lodge's aether, as described in his *My Philosophy* (1933), continued and conflated four Victorian scientific traditions: a harmonious relationship between science and religion found in the writings of Maxwell, Stokes and William Thomson; psychical research, which had shown Lodge the reality of life after death; a premium on the unity of knowledge; and Victorian physicists' predilection for pictorial models of physical processes. The aether thereby answered Lodge's need to unify the organic and the inorganic, the spiritual and material, and the scientific and religious.

CANTOR & HODGE's book is a collection of essays from 10 leading historians of the aether. This remains one of the best books on the subject, not least for its consistent emphasis on the different theories as products of broader intellectual culture rather than a set of isolated concepts. Furthermore, each essay shows the kinds of historiographies demanded by aethers of a particular period. Four authors examine the Newtonian aethers in the 18th century: Heimann discusses imponderables; French examines physiology; Christie studies chemistry; and Cantor examines the theological significance of aethers. Despite the editors's claim for the fluidity of aether concepts within their chosen time period, a crucial historical discontinuity seems to have occurred during the 1820s, after which time "aether" became "ether" and subsequently performed specific functions within the emerging physical sciences. Hence, the following papers include Buchwald exploring the aether as a well-defined set of mathematical problems, and Siegel on how a universal dynamical aether functioned in Kelvin and Maxwell's project to unify heat, optics and electromagnetism. Wise's valuable essay powerfully traces the metaphysical roots of German field and aether concepts. The book includes a useful bibliography of secondary sources.

WYNNE explores the social functions of concepts of the aether by connecting Victorian Cambridge intellectuals' interests in physics, psychical research, and Tory politics. Their theorising on the aether and exploration of spiritual phenomena, he argues, were expressions of their political, moral, and social ideology: disclosure of a spiritual or transcendent order in the laboratory or the séance would undermine the materialistic viewpoint, while the declared unifying and spiritual properties of the aether would buttress their predominantly Tory political values against the socially disruptive and demoralising threats of industrialisation, mercantilism, and liberalism. Although crucial factual errors make his argument much stronger than it should be, Wynne's central contention remains tantalising.

HUNT shows that celebrated interpreters of Maxwell, such as George Francis FitzGerald and Oliver Lodge, devised mechanical models of the aether to explore, clarify, and

illustrate key features of Maxwell's electromagnetic theories. The plausibility of these models derived from a strong Victorian tradition regarding aether and matter as fundamentally mechanical: for example, FitzGerald's vortex-sponge model conflated a Berkeleyan emphasis on matter in motion and a tradition of simple, complete and unified mechanical theories of the aether. Hunt also explores the crucial British and German hostility to the ontological significance of these models.

RICHARD NOAKES

See also Electromagnetism; Einstein; Maxwell; Michelson; Spiritualism

Affinity

Duncan, A.M., "The Functions of Affinity Tables and Lavoisier's List of Elements", *Ambix*, 17 (1970): 28–42

Hesse, Mary, *Forces and Fields: The Concept of Action at a Distance in the History of Physics*, London: Nelson, and New York: Philosophical Society, 1961

Jammer, Max, *Concepts of Force: A Study in the Foundations of Dynamics*, Cambridge, Massachusetts: Harvard University Press, 1957

Levere, Trevor H., *Affinity and Matter: Elements of Chemical Philosophy, 1800–1865*, Oxford: Clarendon Press, 1971

Metzger, Hélène, *Newton, Stahl, Boerhaave et la doctrine chimique*, Paris: Alcan, 1930

Nye, Mary Jo, *From Chemical Philosophy to Theoretical Chemistry: Dynamics of Matter and Dynamics of Disciplines, 1800–1950*, Berkeley: University of California Press, 1993

Roberts, Lissa, "Setting the Table: The Disciplinary Development of Eighteenth-Century Chemistry as Read Through the Changing Structure of Its Tables", in *The Literary Structure of Scientific Argument: Historical Studies*, edited by Peter Dear, Philadelphia: University of Pennsylvania Press, 1991, 99–132

Schofield, Robert E., *Mechanism and Materialism: British Natural Philosophy in an Age of Reason*, Princeton, New Jersey: Princeton University Press, 1970

Thackray, Arnold, *Atoms and Powers: An Essay on Newtonian Matter-Theory and the Development of Chemistry*, Cambridge, Massachusetts: Harvard University Press, and London: Oxford University Press, 1970

Tsukahara, Togo, *Affinity and Shinwa Ryoku: Introduction of Western Chemical Concepts in Early Nineteenth-Century Japan*, Amsterdam: Gieben, 1993

In this entry, affinity denotes a concept explaining the capabilities of chemical elements to combine. (Affinity sometimes refers to morphological similarities between natural history specimens, but this is not the usage explored here.) Since affinity is used in explanations relating to the behavior of physical bodies, it is relevant to the history and evolution of subjects such as physics, chemistry, and mineralogy, and it thus underscores the difficulties that exist in determining disciplinary distinctions within the physical sciences. This is a point raised by NYE, who uses the problem of categorizing people who define chemical affinity as a way of illustrating institutional and disciplinary dynamics in physics and chemistry.

Historically, chemical affinity is largely treated as a metaphysical issue but it is implicated in a central concern of the history of chemistry: do particles unite based on their physical properties, or are they held together by attractive forces or imponderable fluids? Thus, while relating to empirical accounts of chemical reactions, problems of affinity are frequently taken as metaphysical problems regarding the cause of combination.

Historiographic treatments of affinity commonly situate the debate within ancient, early-modern, and modern chemical philosophy. JAMMER is interested in the structure of philosophical debates, and his study analyses the logic in the construction of arguments about the concept of force. Rather than emphasising the philosophical challenges to the uses of this concept in physics (as those mentioned below), he looks for similarities in thought that associate force with what later becomes "work" in thermodynamics. Jammer adopts a broad chronological scope, tracing the development of these ideas from ancient Greece to modern Germany. Chemical affinity in particular is shown to be related to theories of mechanical phenomena or universal gravitation.

HESSE is also interested in the logical construction of theories of force that act on physical entities by considering, for example, realist arguments or hypothetico-deductive methods. She explores analogies and theoretical models in physics which work to illustrate the problem of bodies acting on one another at a distance. Like Jammer, Hesse works within a broad chronology, including atomism in antiquity, Cartesian mechanism, 18th-century elastic fluid theories, and the development of relativity theories. "Chemical affinity" is nowhere dealt with *per se*, but is discussed in relation to Newton's queries on the role of attraction and repulsion in the cohesion of particles. Hesse also discusses the problem of "action at a distance" in relation to philosophical considerations; for example, how metaphysical issues of spiritualism, voids in space, or ultimate particles were dealt with in religious and philosophical debate.

Within the framework of the development of modern chemistry, THACKRAY studies how Isaac Newton dealt with the forces that determine the structure of matter, and the subsequent spread of "Newtonianism", which here is a loosely defined methodological prescription that chemistry should be quantified through the measurement of forces. For Thackray, the effect of the "Cartesian legacy" on the philosophy of chemical combination was replaced by that of affinity theory, through the work of Newtonian experimental philosophy. Newton struggled with the problem of chemical combination and affinity, but his treatment of the problem was left incomplete. Newton raised the issue in "Query 31" of his *Opticks*, in which he stated: "Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance", but then left this as a proposition for the engagement of his successors. Thackray considers the ways in which 18th-century natural philosophers, such as Buffon, Macquer, and Bergman, worked with Newtonian equations for gravitational attraction in order to mathematicize laws of chemical affinity. An innovative research strategy for many of these scientists was assembling affinity tables, used to depict the degrees of force between chemicals. While Thackray places

Newton's work in connection with a subsequent research programme, METZGER concentrates on how the specific concept of chemical affinity is dealt with in the work of her three chosen individuals: Newton, Georg Ernst Stahl, and Herman Boerhaave. The affinity tables are discussed by DUNCAN and ROBERTS, who look at the relations between a particular aspect of chemical practice in the 18th century – the construction of affinity tables – and the way chemists defined their own scientific enterprise. Duncan lists how a number of 18th-century European chemists defined concepts of affinity, and then used different affinity tables to determine quantitatively the amounts of force in chemical attractions. Roberts considers how the growing uses of mathematics in chemistry in the 18th century, as represented in the increasing centrality of affinity tables, affected disciplinary views about the practice of chemistry.

Newtonian mathematical models are central to the study by SCHOFIELD. He focuses mainly on 18th-century debates on whether particles combined by their material shapes or by Newtonian forces acting at a distance, and examines how Newton's attempts to reconcile 17th-century corpuscularism with his ethereal philosophy were refined by his successors. Schofield adopts the tags "materialism" and "mechanism" to refer to the ways in which 18th-century materialists departed from the Aristotelian, scholastic tradition of associating primary particles with essential properties which determine chemical union, by invoking Newton's mechanism for active forces as a cause for the phenomenon.

LEVERE pursues and clarifies Schofield's account of this conceptual shift by extending the study to the 19th century. He examines the way a group of 19th-century chemists modified the concept of chemical affinity, and considers how experimental practices formed heuristic models with which chemists were able to conceptualise actions of affinity, and how metaphysical problems arising from the action of these invisible powers affect knowledge claims. Humphry Davy's experiments with the galvanic battery on the decomposition of matter are shown to provide a link between Davy's belief that all matter was electrically endowed and his association of chemical affinity with electricity. Levere then discusses at some length the impact of Michael Faraday's work on electrolytic decomposition, and Jacob Berzelius's and his contemporaries' researches in galvanism on the development of European chemical experimentation. Throughout, Levere emphasises individual biography, and the connections between chemical theory and contemporary philosophy and religion.

Finally, TSUKAHARA makes the concept of chemical affinity central to his account of the transfer of chemical theory from the West to Japan in the 19th century. He succinctly traces the history of the mechanical and dynamic conceptions of affinity in the West, then discusses conditions in Japan that made the transfer of this chemical theory difficult. In Japan, Buddhism, Shintoism, and Confucianism maintained different epistemological positions regarding atomic entities, their properties and interactions. Tsukahara reveals how Japanese natural philosophers, who attempted to engage with Western experimental practices, were forced to reconfigure their underlying metaphysical beliefs concerning invisible forces, and their propositions about the fundamental properties of matter.

BRIAN DOLAN

Africa: south of the Sahara

Doumbia, Salimata (ed.), *Mathématiques dans l'environnement socio-culturel Africain*, vol. 1, Abidjan: Institut de Recherches Mathématiques, 1984

Gerdes, Paulus, *Ethnogeometrie: Kulturanthropologische Beiträge zur Genese und Didaktik der Geometrie*, Bad Salzdethfurth/Hildesheim: Franzbecker, 1991

Gerdes, Paulus, *Geometria SONA: Reflexões sobre uma tradição de desenho em povos da África ao Sul do Equador*, 3 vols, Maputo: Instituto Superior Pedagógico, 1993–94; as *Une Tradition géométrique en Afrique: Les dessins sur le sable*, 3 vols, Paris: L'Harmattan, 1995

Gerdes, Paulus, "On Mathematics in the History of Sub-Saharan Africa", *Historia Mathematica*, 21 (1994): 345–76

Gerdes, Paulus and Gildo Bulafo, *Sipatsi: Technology, Art and Geometry in Inhambane*, Maputo: Instituto Superior Pedagógico, 1994

Liebenberg, Louis, *The Art of Tracking: The Origin of Science*, Claremont, South Africa: Philip, 1990

Niangoran-Bouah, G., *L'Univers Akan des poids à peser l'or* (English and French texts) 3 vols, Abidjan, Nigeria: Nouvelles Éditions Africaines, 1984–87

Obenga, Théophile, *La Philosophie africaine de la période pharaonique, 2780–330 avant notre ère*, Paris: L'Harmattan, 1990

Thomas-Emeagwali, Gloria (ed.), *The Historical Development of Science and Technology in Nigeria*, Lampeter, Wales, and Lewiston, New York: Edwin Mellen Press, 1992

Thomas-Emeagwali, Gloria (ed.), *Science and Technology in African History with Case Studies from Nigeria, Sierra Leone, Zimbabwe, and Zambia*, Lampeter, Wales, and Lewiston, New York: Edwin Mellen Press, 1992

Thomas-Emeagwali, Gloria (ed.), *African Systems of Science, Technology and Art: The Nigerian Experience*, London: Karnak House, 1993

Van Sertima, Ivan (ed.), *Blacks in Science: Ancient and Modern*, 2 vols, New Brunswick, New Jersey: Transaction Books, 1983

Zaslavsky, Claudia, *Africa Counts: Number and Pattern in African Culture*, Boston: Prindle Weber and Schmidt, 1973

Most histories of mathematics, science and technology devote a few pages to ancient Egypt and to northern Africa during the "Middle Ages". The history of science and technology in sub-Saharan Africa – like the history of Africa south of the Sahara in general – however, has only relatively recently enjoyed increased attention, as Eurocentric views have been losing their grip on historiography. The emerging literature can be divided into several genres: surveys based on a critical appraisal of existing written sources; studies that reflect on the methodology of reconstructing the history of science and technology within a context where few written sources are available; and analyses of specific themes using an interdisciplinary approach – from oral history and ethnography to archaeology.

In her classic study, ZASLAVSKY offers a preliminary survey of the available literature on the history of mathematics in

sub-Saharan Africa. She discusses written, spoken and gesture counting, number mysticism, concepts of time, numbers and money, weights and measures, record-keeping (sticks and strings), mathematical games, magic squares, graphs, and geometric form; in addition Crowe contributes a chapter on geometric symmetries in African art. An overview of research findings since the publication of Zaslavsky's book can be found in GERDES (1994), along with sources on or related to mathematics in African history. Several references to physics, astronomy, cosmology, logic, philosophy, and technology are also included.

Several chapters of VAN SERTIMA deal with the history of science in Africa. Pappademos revises conventional assumptions about the role of Africans in the history of physics by outlining some of their contributions to measurement, mechanics, optics, astronomy, and metallurgy. Lynch and Robbins analyse evidence from Namoratunga, a megalithic site in north-western Kenya, that suggests that a prehistoric calendar based on detailed astronomic knowledge was in use in east Africa (c.300 BC). Lumpkin discusses the place of Africa in the mainstream of the history of mathematics.

THOMAS-EMEAGWALI (1993) includes a chapter on conceptual and methodological issues in science and technology in Nigerian history. The third and fourth chapters of GERDES (1991) are dedicated to the methodology of reconstructing elements of the early history of geometrical thinking through study of the relationships between the development of geometrical knowledge and socially/culturally important activities such as mat and basket weaving, pot making, and house building in Africa.

The emergence of scientific thinking in African hunter-gatherer societies is studied by LIEBENBERG. The principles of tracking, classification of signs, and spoor interpretation among the hunter-gatherers of the Kalahari in southern Africa are analysed. The book presents the hypothesis that the development of tracking probably played a significant role in the evolution of the scientific faculty. "The critical attitude of contemporary Kalahari Desert trackers, and the role of critical discussion in tracking suggest ... that the rationalist tradition of science may well have been practised by hunter-gatherers long before the Greek philosophic schools were founded."

The first volume of GERDES (1993–95) is dedicated to the analysis and reconstruction of mathematical elements in the sand drawing tradition of the Tchokwe and neighbouring peoples in Angola, Zaire and Zambia. Symmetries, classes, and algorithms for the execution of the drawings (called sona), and rules for the systematic construction of monolinear sona, are among the themes analysed. Volume 2 explores the educational and scientific potential of the (reconstructed) sona tradition, whereas volume 3 analyses traditions from ancient Egypt and Mesopotamia, from the Tamil of southern India, from the Celts of northern Britain and from North American Indians, which, from a technical point of view, bear similarities to the African sona tradition.

DOUMBIA analyses mathematical aspects of verbal calculation, gambling and board games of the Ivory Coast. GERDES & BULAFO study the development of the technological and geometrical knowledge of basket weavers in Mozambique's Inhambane province.

Each section of OBENGA contains the reproduction of an ancient Egyptian text, its translation and commentaries. A section on calendars includes a comparative description of ancient Egyptian, Fang, Mbochi (Congo), Borana (Ethiopia) and Dogon (Mali) astronomy. A section on metrology includes a comparison between the measures and numeration in ancient Egypt and the ones used by the Duala (Cameroon), Fang (Cameroon, Equatorial Guinea, Gabon), Yoruba (Nigeria), Ganda, BaNgongo (Congo) among others. NIANGORAN-BOUAH contributes to the reconstruction of the history and use of the gold weights of the Akan (Ghana, Ivory Coast).

Essays in THOMAS-EMEAGWALI (1992, *The Historical Development of Science and Technology in Nigeria*) analyse traditional methods of food processing, cassava-processing technology, textile technology, and pedagogy and science teaching in Nigeria. The text concentrates on the historical dimension, but approaches the subject within the context of multidisciplinary interpretation. THOMAS-EMEAGWALI (1993) includes essays on textile technologies of the 19th and early 20th centuries, traditional medicine, food processing, metal technology, and mechanics and engineering – the construction of fortifications – in pre-colonial Nigeria. THOMAS-EMEAGWALI (1992, *Science and Technology in African History*), presents case studies in the history of science and technology from Nigeria, Sierra Leone, Zimbabwe, and Zambia. In science, the areas of focus include arithmetic (pre-colonial central Sudan) and traditional medicine, as well as biologically-based warfare and control of water-based diseases (Nigeria). In technology, metallurgy (Nigeria), gold (Zimbabwe) and diamond mining (Sierra Leone), and glass-making (Nigeria) are studied. Two chapters discuss science and technology policies in Zambia and Nigeria, and the final chapter is dedicated to historical perspectives on technical co-operation in Africa. Kani concludes his contribution on arithmetic in pre-colonial central Sudan with the following criticism:

> Despite the availability of a great deal of literature on medicine, astrology, arithmetic and other related sciences, written in Arabic, Fulfulde, Hausa and other languages, little effort has been made to systematically study these sciences within the historical perspective. The intellectual output of the *cUlama* [scholars] in this area has been wrongly classified by our contemporary historians and social scientists under the rubric of "mysticism". A serious investigation into the literary output of the scholars of western and central Sudan, however, may reveal the fact that these scholars had explored agricultural, medicinal, astronomical and mathematical sciences long before the advent of colonial rule.

PAULUS GERDES

See also Astronomy: non-European; Ethnomathematics; Ethnoscience; Metrology

Africa: health and healing

Abdalla, Ismail H., *Islam, Medicine, and Practitioners in Northern Nigeria*, Lampeter, Wales, and Lewiston, New York: Edwin Mellen Press, 1997

Ackerknecht, Erwin Heinz, *Medicine and Ethnology: Selected Essays*, edited by H.H. Walser and H.M. Koelbing, Baltimore: Johns Hopkins Press, 1971

Conrad, Peter and Eugene B. Gallagher (eds), *Health and Health Care in Developing Countries: Sociological Perspectives*, Philadelphia: Temple University Press, 1993

Curtin, Philip D., *Disease and Empire: The Health of European Troops in the Conquest of Africa*, Cambridge and New York: Cambridge University Press, 1998

Evans-Pritchard, E.E., *Witchcraft, Oracles and Magic among the Azande*, with a foreword by C.G. Seligman, Oxford: Clarendon Press, 1937

Falola, Toyin and Dennis Ityavyar (eds), *The Political Economy of Health in Africa*, Athens: Ohio University Center for International Studies, 1991

Feierman, Steven, *Health and Society in Africa: A Working Bibliography*, Waltham, Massachusetts: Crossroads Press, 1979

Feierman, Steven, *Peasant Intellectuals: Anthropology and History in Tanzania*, Madison: University of Wisconsin Press, 1990

Feierman, Steven and John M. Janzen (eds), *The Social Basis of Health and Healing in Africa*, Berkeley: University of California Press, 1992

Harrison, Ira E. and Sheila Cosminsky, *Traditional Medicine: Current Research with Implications for Ethnomedicine, Ethnopharmacology, Maternal and Child Health, Mental Health and Public Health: An Annotated Bibliography of Africa, Latin America, and the Caribbean*, 2 vols, New York: Garland, 1976–84

Jacobson-Widding, Anita and David Westerlund (eds), *Culture, Experience and Pluralism: Essays on African Ideas of Illness and Healing*, Stockholm: Almqvist & Wiksell, 1989

Janzen, John M., *The Quest for Therapy in Lower Zaire*, Berkeley: University of California Press, 1978

Janzen, John M. and Steven Feierman (eds), "The Social History of Disease and Medicine in Africa", *Social Science and Medicine*, special issue 13 B/4 (1979): 239–356

Janzen, John M. and Gwyn Prins (eds), "Causality and Classification in African Health and Medicine", *Social Science and Medicine*, special issue 15 B/3 (1981): 169–437

Last, Murray, and G.L. Chavunduka (eds), *The Professionalisation of African Medicine*, Manchester: Manchester University Press/International African Institute, 1986

Loudon, J.B., *Social Anthropology and Medicine*, London and New York: Academic Press, 1976

Packard, Randall M., *White Plague, Black Labor: Tuberculosis and the Political Economy of Health and Disease in South Africa*, Berkeley: University of California Press, 1989

Sigerist, Henry E., *Primitive and Archaic Medicine*, Oxford and New York: Oxford University Press, 1951

Slikkerveer, Leendert Jan, *Plural Medical Systems in the Horn of Africa: The Legacy of "Sheikh" Hippocrates*, London and New York: Kegan Paul, 1990

Ulin, Priscilla R. and Marshall H. Segall (eds), *Traditional Health Care Delivery in Contemporary Africa*, Syracuse, New York: Maxwell School of Citizenship and Public Affairs, 1980

Vaughan, Megan, *Curing Their Ills: Colonial Power and African Illness*, Stanford, California: Stanford University Press, 1991

Yoder, P. Stanley (ed.), *African Health and Healing Systems: Proceedings of a Symposium*, Los Angeles: African Studies Center, 1982

It would be arrogant to attempt to summarize the history or the historiography of health and healing in Africa before defining what is meant by "health", "medicine", "healing", and "Africa". As a geographic entity, the continent of Africa has relatively clear boundaries, though the political and cultural boundaries within Africa and between Africa, Europe, and Asia have been more fluid. Culturally, politically, and economically, however, the North African countries on the Mediterranean, the West African countries that face the Atlantic, the East African societies with ties to the Middle East, and the southern African peoples are quite different from one another. The diversity of the African peoples and traditions, the varieties of social organization, and the differences in economies and ways of life, as well as many other factors, suggest that healing may be practiced differently, by different kinds of healers, and have varied social, political, technological, and material bases. What constitutes a healing activity is similarly difficult to articulate, since the boundaries between public and private, religion and medicine, and cure and care map differently compared to the Western doctor-patient relationship, in addition to varying from tradition to tradition and from place to place. These caveats make it crucial for the interested reader to consult materials on the specific peoples, places, and healing traditions of interest, and to be wary of making generalizations for other places, periods, peoples, or healing systems.

The study of health and healing in Africa has changed since Erwin Ackerknecht, Henry Sigerist, and E.E. Evans-Pritchard conducted studies of "primitive medicine" in Africa in the 1930s. SIGERIST and ACKERKNECHT displayed considerable sophistication in their analysis of medicine and culture, but their faith in modernism and in science as its tool to ease suffering and to bring greater equality of peoples now looks somewhat naive. African independence from colonial rule, the dialogue between European and African scholars of African cultures, and changes in the theoretical stances of anthropology have changed who studies whom, what, and for what purposes. Recent approaches have addressed the links between healing systems and cultures, and the coexistence of multiple healing traditions within particular societies. What has not changed but instead has expanded in histories of Western medicine in Western societies is the realization that, as Feierman notes in the introduction to his 1979 bibliography:

> It is immediately clear to anyone attempting to define the scope of relations among medicine, disease, and social organization in Africa (or anywhere else) that no

> aspect of social life or human biology can legitimately be excluded. Changing settlement patterns, for example, lead to changes in disease patterns, which lead in turn to modified settlement patterns and sometimes to government intervention, producing in turn its own response. An individual who is ill might make use of local herbal knowledge or examine his or her place in neighborhood patterns of relationship, consult a diviner or attribute the illness to witchcraft, take part in a therapeutic spirit possession rite or visit a teacher learned in Islam, visit a hospital or simply go untreated.

The choice of terminology is important, since explicit or implicit comparisons to biomedicine have been encoded into many descriptions of ethnomedical practice. "Primitive" medicine has invidious evolutionary connotations in its comparison to "modern" medicine. "Traditional" medicine and "ethnomedicine" are used more flexibly, though they still reinforce the sense that ethnomedicine is unchanging or timeless, and by implication that traditional healers are uninterested in furthering their skills or learning new modalities.

Traditional African health and healing has been the province of anthropologists, sociologists, demographers, and historians. FEIERMAN (1979) and HARRISON & COSMINSKY provide entrées into the historical and anthropological literature on African health and healing. The essays in FEIERMAN & JANZEN give an introduction to the issues in African historical demography, African healing systems, and medicine in Africa before, during, and after the colonial period. This book is the best introduction to the central issues and aspects of the social study of African health. EVANS-PRITCHARD's discussion of Zande culture and the ways in which illness was explained and understood set a standard for ethnographic detail. Evans-Pritchard paid little attention to Zande disease classifications, and instead addressed their causal explanations based in witchcraft and spirit life. Though natural and supernatural explanations often existed for the same disease or accident, the power of supernatural explanations to answer the question "why me?" contributed to their importance. JANZEN & FEIERMAN and JANZEN & PRINS present important symposia discussing a variety of healing systems within different African cultures. Their emphases on health preservation and restoration as part of a larger social fabric of war, colonialism, and gender politics as well as the health valences of traditional settlement patterns, food production, and ways of cooking, place these works firmly within social anthropology as well as more narrowly medical anthropology. The essays in Janzen & Prins are particularly valuable for their discussions of disease causality, both personalistic (usually supernatural or intentional) and naturalistic (the sort of sickness that "just happens"). LOUDON presents a collection of essays on various diseases, treatment systems, and systems for explaining illness and misfortune, including an important essay by Gillies on "Causal Criteria in African Classifications of Disease". YODER's edited volume is also predominantly interested in explaining healing systems and the interaction among patients, families, and healers in eight case studies. Some of these take the approach of public health or that of health planning, providing a less individualistic perspective on health and healing, and the two commentaries included on the study of African healing are valuable. FEIERMAN (1990) reminds the reader of the importance of change over time in Tanzania and the colonial history of the Shambaai peoples. Caring for people and the land and the interaction of colonial rulers and "peasant intellectuals", wisdom, and local knowledge are at the center of this work. Finally, VAUGHAN presents an evaluation of biomedicine as a colonial tool and contributes to the understanding of psychiatry and mental health as cultural phenomena. Her discussion of missionary medicine and government health education places health in a colonial discourse of politics, religious conversion, and economic exploitation. The portrait of the colonial administrator attempting to understand what counts as insanity in another culture, whose task is mystified rather than clarified by the use of a translator, since rendering another's words means giving them form and structure, is almost comic.

The presence of multiple healing systems in most African cultures, especially after colonization and biomedicine, has presented patients or their advocates with choices for the treatment of illness and misfortune. JANZEN (1978) gave the first forceful demonstration of therapeutic choice and the role of lay therapy managers in navigating the varied possibilities for explaining and treating illness. This work has been important in shifting the emphasis in the field from a view of biomedicine or traditional medicine as a simple and firm choice, and also in leading to the conclusion that therapeutic systems are not firmly or solely linked to a single cultural group, with each group having its own healing tradition. ABDALLA has pointed out the importance of Islamic prophetic healing as a third alternative in many places, including northern Nigeria, whose plurality of healing cultures he examines among the Hausa over the past four centuries. JACOBSON-WIDDING & WESTERLUND use pluralism as a guiding idea, and cultural anthropology and phenomenology as methods. A notable contribution by Susan Reynolds Whyte explores what it means to compare different African healers to biomedicine rather than to religious leaders. What, in the context of the East African cults of affliction, is the difference between religion and medicine? The contributors to ULIN & SEGALL present traditional medicine as part of a "worldwide drive to make health care accessible, affordable, and culturally relevant for all people". Similar concerns have been seen in the explicit endorsement of Chinese traditional medicine by the government of China since 1949 and the implicit license given to Curanderos in Mexico, where they provide primary health care to many in the population. SLIKKERVEER discusses the balance between biomedicine, Islamic medicine, and other healing systems in the northeast corner of Africa, largely in the present, as a contribution to health systems research and health policy. Slikkerveer argues that if biomedicine is unable to reach the rural populations, and the first therapeutic choice (help-seeking behavior) of individuals and groups is for other modalities, then this should be understood and used to advantage in health planning. The potentials of traditional healing as primary care viewed both by government officials and by healers themselves are most clearly addressed by the contributors to LAST & CHAVUNDUKA, who study the efforts of traditional healers to gain the protections of licensure and systematic control of training through professionalization and present in stark relief some of the questions of modernization,

urbanization, population growth, commodification of health and healing and the legitimacy of traditional healing in post-colonial Africa.

Life and death as expendable or purchasable commodities rarely present an encouraging view of human nature. None the less, health conditions have been crucial to colonization, land use, labor, and trade. CURTIN explores the improvement of mortality rates in European military services in the mid-19th century. The improvement of mortality rates for troops occurred just before the waves of African colonization, and could not have been unrelated, he argues. PACKARD explores miners phthisis or tuberculosis among black diamond and gold miners in South Africa. The importance of nutrition and working conditions to life expectancy, and of political and economic power to the determination of those conditions, is a reminder of the class and race implications of employment policies and how and when money can buy or sell lives. FALOLA & ITYAVYAR include essays on African health services and health conditions with an emphasis on contemporary biomedical health service delivery, colonialism and its effects on African countries, and local versus international health planning. CONRAD & GALLAGHER also provide contemporary accounts from a health-services perspective, and place three pieces on Africa within a thematic organization that includes accounts of East Asian, Latin American, and other cultures.

The trade in ideas, medicinal substances, and practices that has led to the use of herbal medicines, charms, and divination in industrialized countries in European cultures is a separate movement. While the availability or visibility of ideas and practices from Africa in European cultures is the result of the usual rounds of trade, migration, and warfare that have been mixing peoples and their cultures for centuries, the critiques of science, technology, Western medicine, racism, and colonialism that are often encoded in the use of African healing modalities outside their cultures of origin highlight the importance of health and healing as part of larger social and cultural trends.

Interested readers are advised to search for monographs and articles on the specific traditions, peoples, or countries that interest them, since this summary is necessarily selective. Synthetic works on medical anthropology also often contain valuable material on particular traditions. A substantial volume of additional work exists in other fields relevant to African health conditions, including the contemporary demography of health and illness in Africa, particular diseases, population policy, and agriculture and food production.

CARLA KEIRNS

See also Traditional Medicine

Age of the Earth

Albritton Jr, Claude C., *The Abyss of Time: Changing Conceptions of the Earth's Antiquity after the Sixteenth Century*, San Francisco: Freeman Cooper, 1980

Burchfield, Joe D., *Lord Kelvin and the Age of the Earth*, New York: Science History Publications, 1975; with new afterword, Chicago: University of Chicago Press, 1990

Dalrymple, G. Brent, *The Age of the Earth*, Stanford, California: Stanford University Press, 1991

Dean, Dennis R., "The Age of the Earth Controversy: Beginnings to Hutton," *Annals of Science*, 38 (1991): 435–56

Gould, Stephen Jay, *Time's Arrow, Time's Cycle: Myth and Metaphor in the Discovery of Geological Time*, Cambridge, Massachusetts: Harvard University Press, 1987

Haber, Francis C., *The Age of the World: Moses to Darwin*, Baltimore: Johns Hopkins University Press, 1959

Rossi, Paolo, *The Dark Abyss of Time: The History of the Earth and the History of Nations from Hooke to Vico*, translated from the Italian by Lydia G. Cochrane, Chicago: University of Chicago Press, 1984 (original edition, 1979)

Rudwick, Martin J.S., "The Shape and Meaning of Earth History," in *God and Nature: Historical Essays on the Encounter Between Christianity and Science*, edited by David C. Lindberg and Ronald L. Numbers, Berkeley: University of California Press, 1986

The problem of determining the age of the Earth cuts across disciplinary boundaries: answers to the question, "How old is our world?" have been derived from biblical exegesis, physics, astronomy, chemistry, and various branches of geology. The implications of those answers, though felt most forcefully by geologists, have also reshaped ideas about biology, theology, and the aesthetics of nature. The literature on the age-of-the-Earth question is, accordingly, diverse and wide-ranging.

Western ideas about the age of the Earth were shaped, from ancient times to the end of the 18th century, principally by religious considerations. DEAN provides an overview of this era, briefly discussing Egyptian, Greek, Roman, and Jewish ideas before turning in detail to those of medieval Christendom. Criticism of these religiously oriented cosmologies began with the writings of medieval Aristotelians, Dean argues, and gained momentum in the Renaissance and Enlightenment as new methods of Biblical scholarship called old assumptions into question. Growing doubts about the literal reliability of Genesis led to the emergence, in the 18th century, of new chronologies which rested on geological rather than textual evidence.

Haber and Rossi both chronicle in detail the undermining and eventual collapse of Bible-based geochronologies. HABER's treatment spans the period between the recognition of fossils as once-living creatures in the 17th century and the publication of Darwin's theory of evolution in the mid-19th century, focusing on the way in which the new scientific ideas challenged and undermined orthodox Christian beliefs concerning Earth history. ROSSI's treatment covers a shorter period in greater depth and more intricate detail. It traces the evolution of early modern ideas about fossils, human history and language, while exploring their ties to each other and to the broader philosophical movements of late-17th and 18th-century Europe. Rossi argues that, in combination, these sets of new ideas created an entirely new view of the world's age and history that replaced the older view rooted in Christian orthodoxy. Haber, though somewhat dated and best read in conjunction with more recent works on science and religion, is the more accessible of the two treatments. Rossi's

wide-ranging, philosophically subtle analysis is more rewarding when read after Haber, or by those who already possess a working knowledge of the ideas of René Descartes, Giambattista Vico, and their contemporaries.

RUDWICK covers much of the same chronological ground as Haber and focuses – as do both Haber and Rossi – on the gradual decline of a Bible-centered view of Earth history. His principal concern, however, is not with specific fossils or Biblical texts, but with the cosmological systems derived from them. Rudwick argues that specific, quantitative estimates of the age of the Earth are less significant than the broad, qualitative patterns that link Earth histories constructed in particular times and places. He traces the impact of new ideas – first in Biblical criticism and later in geology – on these patterns.

DALRYMPLE, a working geologist, is primarily concerned with present-day scientific ideas about the age of the Earth and the data on which they are based. His book begins, however, with a historical survey. The chapter includes a few pages on the Renaissance, but focuses on the 19th and early 20th centuries – after the acceptance of the Earth's vast antiquity, but before the widespread use of radioactive elements as chronometers. Evidently writing with a geological audience in mind, Dalrymple focuses on the "nuts and bolts" of these calculations and makes free use of equations, graphs, and technical terminology. Readers without a scientific background may find the level of detail off-putting, but Dalrymple's remains the best survey of this often-neglected period in the history of geochronology.

ALBRITTON, like Dalrymple, treats the age-of-the-Earth problem as an episode in the history of geology. His book is aimed at a general audience, however, and omits graphs and equations in favor of period illustrations and a focus on the scientific minds behind the key ideas. Albritton sees the discovery of the Earth's antiquity as a central theme in the development of geology. He traces the emergence of the idea that the Earth has a long, complex history by showing its impact on ideas about the history of life, the tempo of geologic change, and the arrangement of the Earth's crust. The book thus functions on two levels: as a history of ideas about the age of the Earth, and as a history of ideas about the course of Earth history. Its concluding chapters cover the same ground as Dalrymple, but with less technical detail.

GOULD's analysis of three major British geologists – Thomas Burnet, James Hutton, and Charles Lyell – is not, strictly speaking, a study of ideas about the Earth's age. It is, rather, an extended reflection on the nature of geologic time, organized around two potent metaphors: time as a journey with a finite beginning and end, and time as an endlessly repeated cycle. Burnet saw the Earth as little older than 6000 years; Hutton and Lyell saw it as unimaginably old. Gould's close analysis of their work traces the scientific, theological, and philosophical implications of their very different views of the past.

The British physicist William Thomson, later Lord Kelvin, triggered an intense debate with a series of late 19th-century papers that attacked Lyell's notion of an unimaginably old Earth. Thomson argued that Lyell and his fellow geologists had overestimated the Earth's age by orders of magnitude, and so challenged the intellectual foundations of both British geology and Darwinian evolution. BURCHFIELD analyzes Thomson's critique, and the responses of British geologists and biologists, in detail. He suggests that Thomson's arguments – a potent force from 1862 until the early 20th century – brought about the much-needed moderation of Lyell's more extreme claims about the age of the Earth and the tempo of geological processes. Burchfield's work, like Albritton's, is written with a broad audience in mind, linking ideas about the Earth's age to contemporary geological practice.

A. BOWDOIN VAN RIPER

See also Archaeology; Geology; Hutton; Prehistory: archaeology and anthropology; Religion and Science: general works; Time

Agricola, Georgius 1494–1555

German humanist and scientist

Adams, Frank Dawson, *The Birth and Development of the Geological Sciences*, London: Baillière Tindall and Cox, and Baltimore: Johns Hopkins Press, 1938

Bandy, Mark Chance and Jean A. Bandy (trans), *De Natura Fossilium*, New York: Geological Society of America, 1955

Dibner, Bern, *Agricola on Metals*, Norwalk, Connecticut: Burndy Library, 1958

Halleux, Robert, "La Nature et la formation des metaux selon Agricola et ses contemporains", *Revue d'Histoire des Sciences*, 27/3 (1974): 211–22

Halleux, Robert and Albert Yans, *Bermannus (Le Mineur): Un dialogue sur les mines*, Paris: Les Belles Lettres, 1990

Hollister-Short, Graham, "The First Fifty Years of the Rod-Engine (c.1540–c.1600)", in *Mining Before Powder*, edited by Trevor D. Ford and Lynn Willies: *Peak District Mines Historical Society: Bulletin*, 12/3 (Summer 1994): 83–90

Hoover, Herbert and Lou Henry Hoover (trans), *De Re Metallica*, London: *Mining Magazine*, 1912; reprinted, New York: Dover, 1950

Naumann, Friedrich (ed.), *Georgius Agricola: 500 Jahre: Wissenschaftlicher Konferenz*, Basel: Birkhäuser, 1994

Suhling, Lothar, "Bergbau und Hüttenwesen in Mitteleuropa zur Agricola-Zeit", in *Zwölf Bücher vom Berg- und Hüttenwesen*, by Agricola, Munich: Deutscher Taschenbuch, 1977, 570–88

Wilsdorf, Helmut, *Georg Agricola und seine Zeit*, vol. 1 of *Ausgewählte Werke*, Berlin: VEB Deutscher Verlag der Wissenschaften, 1956

It is likely that Georg Bauer latinized his name (Bauer = farmer = Agricola) at the University of Leipzig. (The first recorded use is in a receipted account of 1521.) He travelled to Italy to further his medical education in 1523, and spent from 1524 to 1526 working in Venice, preparing the texts of the first printed editions of Galen and Hippocrates. In 1527, after his return to Germany, he took up the position of town physician in St Joachimsthal (Jachymov), a post he held until 1530. These years were spent gathering material for the series of books

on mineralogy, geology, and mining that he was to publish subsequently.

ADAMS, in his survey of the geological sciences from c.1500 to 1814 (the time of Berzelius's work on the chemical composition of minerals), devotes some 10 pages to Agricola, apostrophized as "the father of mineralogy", and as "one of the most outstanding figures in the history of geological science . . . of all time". The discussion is based on the two works in which Agricola developed his ideas about minerals and their classification, the *Bermannus* of 1530, and *De Natura Fossilium* (*Textbook of Mineralogy*) of 1546. In the latter work, Agricola reviews and rejects the ancient systems of classification of Aristotle, Avicenna, and Albertus Magnus, and in the process takes many sideswipes at magical and superstitious beliefs. He proposes instead a systematization based on the physical properties of "fossils"; i.e., of all the kinds of materials, such as earths, stones and minerals, dug from the earth's crust.

Although BANDY & BANDY supply only six pages of prefatory material to their translation, some of which is defective, their appreciation of Agricola's intellectual achievement is sharp and clear. Given the paucity of work in English on Agricola, DIBNER's contribution is to be welcomed, even though the treatment is somewhat elementary. Part of the book consists of a brief and not altogether accurate account of Agricola's life, which could have been corrected in the light of Wilsdorf's scrupulously researched biography of Agricola, a work actually cited in Dibner's bibliography. The bulk of Dibner's work consists of a chapter by chapter description of the 12 books of the posthumous *De Re Metallica* [On Mining] of 1556, with a generous selection of woodcuts from this work providing visual interest.

HALLEUX & YANS preface their translation of the *Bermannus* with a 20-page survey of Agricola's life and work up to the publication of this, his first work on mining, in 1530. Further sections examine the dialogue form that Agricola chose for this work, and its structure. The first part of the dialogue describes the scene of action, the topography of St Joachimsthal (now Jachymov); the second and larger part is an extended exercise in lexicography. The task Agricola set himself was to confront the mineralogical terms found in the classical medical vocabulary with the actual ores and metals extracted from the mountain range between Bohemia and Saxony.

HALLEUX undertakes a critical appraisal of Agricola's *De Ortu et Causis Subterraneorum* [On the Origin and Causes of Sub-Surface Phenomena] of 1546, in which Agricola, in his research into the nature of metals and the origin of their ores, reacted against earlier writers. He added quicksilver, antimony, and bismuth to the six metals of Aristotle, and modified the distinctive properties of metallic bodies. He criticized the Aristotelian theory of two-fold exhalation, and explained metals as frozen juices (*succi*), compounds of earth and water. He also rejected the alchemical ideas of Avicenna, Ibn Juljul, Albertus Magnus, and the Bergbüchlein. His criticism of Aristotle's ideas did not win much support from contemporaries such as Scaliger, Cardano, and Fallopius, but his demolition of the alchemists was successful.

A notion frequently encountered in the literature is that Agricola's *De Re Metallica* of 1556 remained for at least 150 years a standard work of reference for miners. HOLLISTER-SHORT demonstrates that, as far as Book VI of the treatise is concerned, in which Agricola examines the machines used in mining, nothing could be further from the truth. Even before *De Re Metallica* came off Froben's presses in Basel, the speed of the development of a new type of water-pumping engine (the *Stangenkunst* or rod-engine) had already rendered obsolete virtually all of the older devices described by Agricola. The paper then goes on to trace the further development of the rod-engine up to c.1600.

The HOOVERS' preface to their translation of *De Re Metallica* (the only complete work of Agricola's, apart from *De Natura Fossilium*, to have been translated into English) is still the best critical appreciation (in English) of his life and work. Of *De Re Metallica* they remark that "while it is of the most general interest of all his works, yet from the point of view of pure science *De Natura Fossilium* and *De Ortu et Causis* . . . are works which deserve an equally important place". In Appendix A they present translations of key passages from *De Ortu et Causis* . . . in which Agricola refers to the role of erosion in the shaping of the earth's surface. Of greater interest, however, are his views on ore channels, on the origin of ground waters and gangue, and on the origin of metals and "juices" (*succi*). These reveal his belief that the deposition of ores, and the mineralization of rocks in general, took place subsequent to the formation of the containing rocks, and that channels were filled by circulating solutions to form mineralized veins.

The work edited by NAUMANN contains the best of the papers delivered at the symposium held in Chemnitz (Agricola's home from 1533 to 1555) in March 1994 to celebrate the 500th anniversary of Agricola's birth. Most of the 50 or so papers are arranged under six titles, following the pattern of the conference: 1. Agricola's place in the history of medicine, pharmacy, and science (eight papers); 2. the intellectual climate of his time (seven papers); 3. Agricola as a politician and diplomat (seven papers); 4. his work in the field of metallurgy (five papers); 5. his work in mining (11 papers); and 6. his life and times (seven papers). Unfortunately for English readers, only two papers are in English, and only one of these is directly concerned with Agricola himself. This is Nicoletta Morello's study (pp. 73–81) of Agricola's attempt to reconcile ancient and modern mineral nomenclature during the composition of the *Bermannus* of 1530 (the most widely read of all his works in his own time).

SUHLING, in an essay specially written for this reprint of the 1928 German translation of *De Re Metallica*, provides a five-part overview of central European mining and metallurgy in Agricola's time. He reviews: the importance of mining for the region extending from Alsace in the west to central Slovakia in the east; the significance of technological developments for production and as accelerators of social change; the place of *De Re Metallica* in European mining literature; the crisis in European mining in the mid-16th century brought on by imports of cheap silver from America and low-priced iron and copper from Sweden; and the importance of Agricola's work of 1556 for the history of technology. Suhling also supplies a chronological check-list of publications on Agricola from 1819 to 1974. A brief biographical sketch by Wilhelm Treue, also forming part of this appended material, has the great merit of citing a dedicatory letter written by Agricola in March 1546 to Georg von Komerstadt, as preface to his *De Veteribus et*

Novis Metallis [On Ancient and Modern Mining Sites]. This reveals how, even as Agricola rode home to Germany in the autumn of 1526, he was already fired by the ambition to make himself expert in all aspects of mining. The *Bermannus*, the first fruit of that decision, forms the link between Agricola's medical work in Venice and the new direction his research was to take from that time onward – i.e., from the medically valuable products of mining to the art of mining itself.

WILSDORF's study of Agricola's life and times remains the fundamental work of reference. The first quarter of the work consists of preliminary studies dealing with the nature of mining in Agricola's time in terms of zones of exploitation, the role of capital, the nature of mining law, the state of the art in respect of mining technology, the political situation in Saxony and Bohemia, and the situation in respect of previous Agricolan scholarship. Agricola's life and work then follows in a sequence of short chapters, with heavy emphasis on the period up to 1531, at which time he entered the service of Heinrich, Duke of Saxony. Even so, evidence for many important passages in Agricola's life depends on a decidedly sparse documentation. The closing chapters cover the corpus of Agricola's work, published and unpublished, including correspondence, translations, and lost works. Each episode in his life and work is supplied with a reference list of the pertinent literature. Wilsdorf later supplied the entry for Agricola in the *Dictionary of Scientific Biography*. Unfortunately, this is brief and misleading, and of very little value.

GRAHAM HOLLISTER-SHORT

Agriculture

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Wilmot, Sarah, *The Business of Improvement: Agriculture and Scientific Culture in Britain, c.1700–c.1870*, Bristol: Historical Geography Research Group, 1990

Agriculture remains a relatively neglected area in the history of science, despite the richness of the historical record and the breadth of the sciences that have historically been associated with agricultural improvement. Much of the current research remains confined to journals. None the less, there is a developing historiography of agricultural science, which can be divided either by chronology or, more interestingly, by national context.

The starting point for a study of British agriculture must be RUSSELL, who gives a narrative account of the rise and progress of agricultural science from the mid-17th to the mid-20th century. He places particular emphasis on theories of crop nutrition, a topic dealt with in more detail by FUSSELL, who looks at how humus theories of crop nutrition were related to practice, and by MOULTON, who looks at the impact of Justus von Liebig's mineral theory. Russell's commentary centres on the main figures involved but ignores the cultural, social, and political contexts within which they operated. While a useful source, then, one needs to be wary of Russell's rather dated account, which is best supplemented by WILMOT, who looks at how the taste for scientific and technical

improvements in the 18th and 19th centuries shaped (and was shaped by) the rural communities in which these improvements were discussed and implemented. She examines the ways in which different social groups – landowners, tenant farmers, and labourers – were connected to the culture of improvement through local improving societies and strategies such as the awarding of medals and premiums to exemplary practitioners.

What these studies make clear is that 19th-century scientific agriculture was centred on chemistry. This is examined in detail by BERMAN, who, in his first three chapters, examines Humphry Davy's early career at the Royal Institution through a close study of manuscripts and printed material. In this period the Royal Institution functioned primarily as a laboratory for the landed improvers who managed the Board of Agriculture, a quasi-government institution founded in 1793. Taking a Marxist position, Berman shows how institutional factors led to important developments in agricultural chemistry, such as the development of a systematic programme of soil analyses. What Berman also makes clear is that in early 19th-century Britain agriculture was an important site for the development of science, in social and cognitive terms.

Taking a social constructivist view, PALLADINO (1996) has focused more specifically on the 20th century. He draws attention to the often ignored fact that agriculture was an important industry in early to mid-20th-century Britain and suggests that agriculture provides a particularly rich resource for the study of the complex relationship between science, technology, and the economy. Based on a survey of the four most important centres for plant breeding research, his central argument is that the nature of the relationship between theoretical science and technical improvement is a complicated one, grounded in social dynamics. Looking at the administrative and social structure of these centres, Palladino implicitly raises questions of how scientists and farmers interact. This issue is dealt with more fully by PALLADINO (1993), in which he identifies a multiplicity of practitioners and theorists, and examines the ways in which they are related. The negotiation of a social and intellectual space in which scientists could articulate their views about agriculture with authority proved to be of great importance.

PALLADINO (1994) concentrates on the way in which scientific theory – in this case Mendelian genetics – provided the rhetorical leverage for the positioning of science within agricultural discourse. Drawing out important differences between Britain and the US, Palladino argues that conflicts between more practically orientated figures, such as Edward Sloper Beavan, and more theoretically inclined geneticists, such as Sir William Dampier, had the effect of colonising an area of agriculture in much the same way that chemistry came to "scientize" agriculture in the 19th century. In Britain this came much later than it did in the US, where agricultural research was tied more closely to the universities. Palladino's primary interest is in the social organisation of science and technology, and especially the genesis of professional science. Accordingly, while he has written extensively on 20th-century British and American agriculture, his accounts in no way exhaust the topic. Indeed, such a focused attention on an area with which other scholars seem reluctant to engage is in danger of distorting the general picture of agriculture in the 20th century.

While his focus on the professionalization of agricultural science may be in danger of skewing the field, Palladino's study of British and American agriculture illustrates the richness of a comparative approach. His identification of a shift from practical to theoretical research has been more fully treated within the American context by MARCUS. He suggests that in the two decades between 1870 and 1890, the social organisation of agricultural research was such that it is profitable to speak of a shift from "scientific agriculture" to "agricultural science". Where technical and scientific improvement had once been the province of practising farmers, by the turn of the century such research agendas were being set and conducted by professional agricultural scientists based in universities. Similar themes are developed by DUPREE, who examines the political administration of agricultural research in America.

The historiography of American agriculture is much more extensive than that of Britain. Illustrating again the predominance of chemistry in the 19th century, ROSSITER examines the reception and dissemination of ideas concerning crop nutrition by charting Liebig's influence on the theory and practice of American agriculture in the period 1840–80. Focusing her study on three pioneering agricultural scientists and how they reacted to Liebig's ideas, she argues that Liebig's influence proved relatively short-lived. Concentrating on American agriculture in the 18th century, CHAPLIN shows how the modernisation of agriculture in the Lower South entailed the incorporation of Scottish political economy, which in turn generated interest in botany, technology, crop breeding, and technical innovation as strategies for economic development. Chaplin's monograph shows clearly how, at least in agriculture, economic thought and economic practice were intimately related to science and technology. Weaving the intellectual history of political economy and natural science together, she also places these in the local socio-economic context, highlighting at once the multifaceted nature of agriculture and the writing of its history. Taken together, these studies begin to offer a general picture of the development of agricultural science in modernity. A general shift from political economy to chemistry to genetics is evident, although this will undoubtedly need qualification and more detailed examination. Recognising such a trend, TOBEY suggests that the first half of the 20th century has, at least in the US, witnessed the blurring of such boundaries, through the emergence of agronomy and ecology within agricultural discourse.

OSBORNE argues that the growth of natural history societies in 19th-century France was intimately connected with imperialism, an important aspect of the history of agricultural research that is largely absent from the histories of American and British agriculture. In particular, he sees the development of an interest in Algerian agriculture as a product of the mobilisation of scientific organisations within an imperial agenda. More general studies of French agriculture are available. BOULAINE, for example, examines the history of agriculture from prehistory to the 20th century in much the same style as Russell, while the ACADÉMIE D'AGRICULTURE DE FRANCE has focused more narrowly on the two centuries since the French Revolution. One of the most interesting features of French agricultural research was that, unlike in Britain and the US, there was a lasting predominance of private research institutions. The most famous example is that of

Boussingault in Alsace, and it was not until after World War II that government institutes were established. Another important aspect of French agriculture was 18th-century physiocracy, an issue dealt with by FOX-GENOVESE. The physiocrats held that agriculture was the sole source of wealth and, as such, these works illustrate the importance of economic science in Enlightenment agriculture.

Studies of agricultural science, as we have seen, tend to concentrate on individuals or institutions. Rossiter focused on the reception of Liebig, and Liebig has provided an accessible and interesting point of entry in historical studies of agricultural science more generally. Several articles, considering the German, British, and American contexts, deal with his agricultural chemistry. Among these are the *Ambix* essays by MUNDAY, FINLAY, SCHLING-BRODERSEN and BROCK & STARK. Munday, arguing aggressively that Liebig scholarship has failed to take accurate note of the manuscript evidence, suggests that Liebig's turn to agricultural chemistry was part of a more general interest in the transformation of living bodies; a science of "metamorphoses", as he calls it. Finlay traces the reception of Liebig's ideas on agricultural chemistry from 1840 to 1862, when a seventh edition of his work in that area was published. Focusing especially on the German context, Finlay argues convincingly that the revised tone and content of the 1862 edition won back important support from the agricultural community. Brock & Starck look at the way in which Liebig utilised institutional support in Britain, in the form of the British Association for the Advancement of Science, in order to prepare an audience for his agricultural chemistry, while Schling-Brodersen considers the extent to which Liebig can be said to have inaugurated agricultural science in Germany. Also concentrating on Liebig's agricultural chemistry is the volume edited by Moulton, which contains essays examining Liebig's mastery of polemics, particularly in the disputes regarding his mineral theory of crop nutrition, and his general influence on the development of agricultural science. Also covered is Liebig's important contribution to the fertiliser industry. As with Russell, these studies are rather dated and Rossiter's work is, in part, a corrective to this collection.

Agriculture provides an interesting point of entry into wider historiographical debates, such as the professionalization of science, the relationship between science, technology, and economic development, the reception and establishment of ideas within specific communities, and the political aspects of government-funded research. Such fields, however, require further study, while other areas, such as the popularisation of agricultural science, the history of soil analysis, and the history of sewage irrigation, await investigation. It is to be hoped that these fields of research will attract interest in the future.

SIMON A. NIGHTINGALE

See also Liebig; Nutrition

AIDS

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Watney, Simon, *Practices of Freedom: Selected Writings on HIV/AIDS*, London: Rivers Oram Press, and Durham, North Carolina: Duke University Press, 1994

Since the US Federal Health authorities' first warnings in mid-1981 against what later came to be officially termed infection by HIV (Human Immuno Deficiency Virus) and AIDS (Acquired Immuno Deficiency Syndrome), this condition has

been the topic of numerous historical studies. It has also prompted a renewed interest in the history of disease, particularly of those diseases that have been perceived in the West as similar to this unexpected pandemic, such as plagues, sexually transmitted diseases, tuberculosis, hepatitis B, and tropical diseases. To a great extent this editorial boom can be explained by the undisguised bewilderment that AIDS and other new, or newly emerging, infectious diseases – splendidly overviewed by Laurie GARRETT – have produced among the Western elites and common people, who look to the social responses to past diseases in order to find ways to confront more efficiently the new global health challenges.

Mirko Grmek, Randy Shilts, and Dennis Altman supply accounts, from different perspectives, of the outbreak and spread of AIDS in the 1980s. GRMEK reports the process of conceptualization of the new pandemic by North American and European clinical practitioners, epidemiologists and molecular biologists, and provides an interpretation of its origins and spread by incorporating results from the biological and epidemiological history of disease. SHILTS describes, by means of a vivid journalistic diary written in the US, the unstoppable progression of AIDS during the years of panic (1981–85). He denounces the valuable time wasted in the face of this epidemic as a result of the general institutional indifference (in medicine, public health, public and private scientific research agencies, and mass media). These only began to mobilize after the death of the Hollywood star Rock Hudson in October 1985. Finally, in a simultaneously personal and political fashion, ALTMAN accounts for the construction of AIDS as a new plague, and its impact on the American way of life in the age of the New Right and the Moral Majority (up to 1985). He lays particular emphasis on the early and active gay response to the situation, in contrast to the ambiguities in the response of the medical establishment and to the sensationalism of the media.

The two volumes edited by FEE & FOX (1988 and 1992) deal with a number of important issues concerning the social construction of AIDS and of AIDS policies from varied disciplinary perspectives (such as the history of medicine, social studies in medicine and science, political science, cultural studies and epidemiology). But in consonance with the changes in the dominant perceptions of AIDS between 1988 and 1992, the earlier volume emphasizes the analogies between the new pandemic and several historical instances of human diseases, while the later one approaches the history of AIDS as an issue fully inserted within contemporary history. In turn, the volume edited by NELKIN, WILLIS & PARRIS explores the impact of AIDS on social institutions, norms and values, interpersonal relationships and cultural representations.

While all these works, with the exception of Grmek, are excellent examples from a large literature concerned with AIDS in the US, much less attention has been paid to the history of AIDS and of AIDS policies in other parts of the world. Outstanding exceptions are Virginia BERRIDGE's thorough historical work analysing the first 14 years of AIDS policy in the UK, which represents a splendid model for future studies on other European countries; and the reader edited by Claude THIAUDIÈRE on the impact of AIDS on French civilization.

Most of the rest consist of comparative studies of AIDS in different countries – far many more on developed countries than on developing ones and the Third World – primarily focusing on issues of public policy, medical anthropology, public health and/or epidemiology, and rather obliquely on historical ones. KIRP & BAYER approach AIDS policy and politics in the developed world by comparing the responses of 11 industrialized democracies (Canada, Germany, Australia, Spain, Britain, France, The Netherlands, Denmark, Sweden, Japan and, again, the US). In contrast, the study by Edward GREEN deals with AIDS policies in sub-Saharan African countries (Swaziland, Liberia, Mozambique and South Africa) with particular emphasis on the relevant role of traditional healers, along with biomedical practitioners, in the containment of AIDS and other STDs.

Other works have focused on the relationship between AIDS and a number of "hot issues". The work of CHIRIMUUTA & CHIRIMUUTA and The Panos Institute Report by SABATIER *et al.* are written with a critical tone, denouncing racism and xenophobia. Richard and Rosalind Chirimuuta reveal the deeply racist ideology underlying the Western claims that "Africa is at the epicentre of the world AIDS pandemic", while Sabatier *et al.* deal with victimization of people affected by AIDS from the Third and the so-called Fourth Worlds (the destitutes in the First World). In other words, they focus on the use of some groups as scapegoats, as responsible for the origin and/or spread of AIDS. The interrelationship between AIDS and the mass media has been explored by Bernard SEYTRE, apropos of the long dispute between Luc Montagnier and Robert Gallo concerning priority in the HIV discovery and over the financial distribution of the patent rights for it. According to Seytre, beyond the big economic interests concerned, this controversy also represents a remarkably personalist media translation of the Franco–American polemics surrounding research on HIV and AIDS. The volume edited by BERRIDGE & STRONG explores, mainly in the case of the UK, US and France, the relationship between AIDS and Western contemporary history in two different ways: the larger agendas in medicine, public health, and social policy into which AIDS fitted, and AIDS itself as a part of the history of the 1980s.

Last, but not least, personal narratives of AIDS have been provided by individuals who have encountered the condition in a number of differing ways. The virologists Robert GALLO and Luc MONTAGNIER have done so from the perspective of their laboratory research on HIV. The French writer Hervé GUIBERT has described the experience of his own body's reaction to AIDS. Lyndall Stein from the British voluntary organization, the Terence Higgins Trust, with the collaboration of the photographer Stephen Mayes and others from the company Network Photographers, has collected pictures of and texts by people affected by AIDS (MAYES & STEIN). While cultural activists like Douglas CRIMP in the US and Simon WATNEY in the UK have used cultural analysis to explore the social and political meanings of AIDS.

JON ARRIZABALAGA

See also Epidemics; Epidemiology; Molecular Biology

Alchemy

Caron, M. and S. Hutin, *The Alchemists*, translated from the French by Helen R. Lane, New York: Grove Press and London: Evergreen Books, 1961 (original edition, 1959)

Debus, Allen G. and Robert P. Multhauf, *Alchemy and Chemistry in the Seventeenth Century*, Los Angeles: William Clark Memorial Library, University of California, 1966

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Dreyfus, Hubert L., *Alchemy and Artificial Intelligence*, Santa Monica, California: Rand, 1965

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Lindsay, Jack, *The Origins of Alchemy in Graeco–Roman Egypt*, London: Frederick Muller and New York: Barnes and Noble, 1970

Taylor, F. Sherwood, *The Alchemists: Founders of Modern Chemistry*, New York: H. Schuman, 1949; London: Heinemann, 1951

Vickers, Brian (ed.), *Occult and Scientific Mentalities in the Renaissance*, Cambridge and New York: Cambridge University Press, 1984

The alchemist's material goals were traditionally supposed to include the philosopher's stone, which would transmute base metals into gold; the elixir of life, which might be identical with the stone; and the homunculus, a miniature man, generated in a glass jar, who would possess and communicate superhuman knowledge. Alchemists themselves have defined their ultimate aims as intellectual enlightenment and spiritual redemption, to which Carl Gustav Jung and his followers would add psychological integration. Any manipulation of material substances is only a means to an end. Alchemy's scientific value has been hotly debated: did it foster the development of experimental method and sound theory, or only distract attention from the valuable chemical discoveries of practical investigators such as metallurgists, pharmacists, and Fellows of the Royal Society? The terms of this debate have themselves been condemned as inappropriate by scholars who have attempted to understand alchemy and alchemists on their own terms, within contemporary contexts. Controversy often focuses on the 17th century, which witnessed an unprecedented amount of alchemical publication, and the parting of the ways between alchemy and so-called modern science.

TAYLOR's brief but comprehensive survey takes a broad perspective, combining scientific rigour with sympathetic understanding of cultures and world views very different from that of the conventional 20th-century scientist, in which alchemy was, as he puts it, at once a craft and a creed. He traces alchemy's history from its ancient beginnings in far-off lands, through the rise of scientific method in 17th-century England, to its modern mystical and psychological applications. Plentiful illustrations are carefully integrated with the lucid, imaginative text.

HOLMYARD concentrates chiefly on the scientific implications of attempts to find the philosopher's stone, which he identifies with the elixir of life, from ancient China to 18th-century Europe. After the Royal Society's investigations into James Price's alchemical claims in 1783, no learned society since has been willing officially to notice alchemical claims. He sees Boyle's *Sceptical Chymist* (1661) as alchemy's death-warrant, though "it survived in apparent vigour for another century". Newton's interest in alchemy is mentioned, but not investigated. Within its conceptual and temporal limits, this is a thorough and authoritative survey. The glossary of technical terms is particularly useful.

CARON & HUTIN argue that alchemy has no history, in the sense that it claims to be a science that is complete and perfect. Unlike other sciences it does not evolve; rather, it is transmitted. Their lively general introduction covers alchemy's aims, theoretical structure, and methods – which are susceptible to change – from China in the 6th century BC to 20th-century Europe. It is lucidly written, with few technical terms, lavishly illustrated, and enhanced with vivid biographical and technical details, including descriptions of laboratory equipment and a recipe for the elixir of long life. Readers should remember the contingencies of translation: "Evranaeus Philaletha" is better known in England as "Eirenaeus Philalethes".

DREYFUS's trenchant rebuttal of exaggerated claims made for artificial intelligence in the 1950s and 1960s uses alchemists's attempts at transmutation as an analogy for the wishful thinking of pioneer computer programmers. He is unfair to alchemists, who, contrary to his assertion, had reasons to believe transmutation had actually been achieved. (Admittedly, they were not authentically "scientific" reasons.) Dreyfus misses an opportunity to draw an even closer parallel, by comparing the computer's potential with that of the homunculus: "wet engineering" with a vengeance!

Debus's paper in DEBUS & MULTHAUF argues that alchemy inspired "chemical philosophers" such as Paracelsus, Fludd and Van Helmont, who "helped formulate modern science by striving for the same goals as the mechanical philosophers, even though they were encouraged to do so by hypotheses and analogies which we today would reject outright". Multhauf's essay on scientific dialogues argues that the scientific revolution was not simply a sudden leap out of the darkness of antiquarianism and the occult into the "light" of rationalism.

LINDSAY's fascinating, scholarly study is the fourth book of a series on the life and culture of Roman Egypt. He accordingly conveys a strong sense of the links between alchemy and its social context, from Ionia in the 7th century BC to medieval Byzantium. Unfortunately, its sheer practicality was uncongenial to the aristocratic ethos of the mainstream philosophical tradition. Lindsay argues persuasively that its uniting of craft-processes with theoretical thought denied alchemy an accepted place in the ancient world.

DOBBS's important study presents Newton's alchemical investigations in a form that other historians of science have

been unable to ignore. With impeccable scholarship, she combines broad historical perspective with detailed accounts of experiments, arguing that alchemy comprised one of the pillars that supported the structure of Newton's mature science.

VICKERS's compilation of essays is essential reading for students of Renaissance scientific historiography. He and his contributors examine the co-existence and interaction of occult and scientific modes of thinking, even in those scientists who themselves delivered sharp attacks on the occult mentality. Vickers recommends that historians of science should not ignore or deny the presence of this apparent contradiction; they should base their analyses on first-hand study of published texts and unpublished manuscripts, and should refine and deepen the intellectual models they use in attempting to understand the phenomenon. Alchemy is frequently discussed, appearing most prominently in Richard Westfall's contention that Newton derived his concept of force partly from the alchemical active principle.

FAUVEL *et al.* have combined with other contributors to produce a volume on Newton and Newtonianism whose clear style and attractive illustrations appeal to the general reader, while its academic rigour satisfies the demands of scholars. Newton's scientific theories are set within the context of his beliefs about Christian theology and classical culture. Studies of his occult interests, such as Jan Golinski's "The Secret Life of an Alchemist" and Piyo Rattansi's "Newton and the Wisdom of the Ancients", fall naturally into place. According to John Henry's "Newton, Matter, and Magic", Newton's alchemical studies laid the foundation for what eventually became particle physics.

KLOSSOWKI DE ROLA presents "a comprehensive selection of the finest engraved alchemical emblems of the 17th century, brought together for the first time". He transcribes and translates the inscriptions, as well as interprets the pictures, and, eschewing scientific terminology, tries to make alchemy intelligible in its own terms. Ultimately, however, he offers no instant enlightenment, claiming that the lesson of the Ancient Way can truly be learnt only by travelling on it. Reading must be supplemented by practice.

CAROLYN D. WILLIAMS

See also Occult Sciences

Algebra

Beaulieu, Liliane, *La Ribu: N. Bourbaki, 1934–1956*, Paris: Springer, 1995

Berggren, J.L., *Episodes in the Mathematics of Medieval Islam*, New York: Springer, 1986

Birkhoff, Garret, "The Rise of Modern Algebra to 1936", in *Men and Institutions in American Mathematics*, edited by J. Dalton Tarwater, John T. White and John D. Miller, Lubbock: Texas Tech Press, 1976

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Busard, H.L.L., *Jordanus de Nemore, De Elementis Arithmetice Artis: A Medieval Treatise on Number Theory*, 2 vols, Stuttgart: Steiner, 1991

Corry, Leo, *Modern Algebra and the Rise of Mathematical Structures*, Basel: Birkhäuser, 1996

Crowe, Michael J., *A History of Vector Analysis: The Evolution of the Idea of a Vectoral System*, Notre Dame, Indiana: University of Notre Dame Press, 1967; reprinted, New York: Dover, 1985

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Grassmann, Hermann, *La Science de la grandeur extensive*, edited by D. Flamant, Paris: Blanchard, 1994

Klein, Jacob, *Greek Mathematical Thought and the Origin of Algebra*, translated from the German by Eva Brann, Cambridge, Massachusetts: MIT Press, 1968 (original edition, 1934)

Mahoney, M., "The Beginnings of Algebraic Thought in the Seventeenth Century", in *Descartes: Philosophy, Mathematics and Physics*, edited by Stephen Gaukroger, Brighton, Harvester Press, and Totowa, New Jersey: Barnes and Noble, 1980

Moore, G.H., "The Axiomatisation of Linear Algebra: 1875–1940", *Historia Mathematica*, 22/3 (1995): 262–303

Novy, Lubos, *Origins of Modern Algebra*, translated from the Czech by Jaroslav Taver, Prague: Academia, 1973

Rashed, Roshdi (ed.), *Diophante: Les Arithmétiques* (Books 4–7), Paris: Belles Lettres, 1984 (Arabic text with French translation)

Rashed, Roshdi, *Entre arithmétique et algèbre: Recherches sur l'histoire des mathématiques arabes*, Paris: Belles Lettres, 1984

Scholz, Erhard (ed.), *Geschichte der Algebra: Eine Einführung*, Mannheim: Wissenschaftsverlag, 1990

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Sinaceur, Hourya, *Corps et modèles: Essais sur l'histoire de l'algèbre relle*, Paris: Vrin, 1991

Unguru, S., "On the Need to Rewrite the History of Greek Mathematics", *Archive for History of Exact Sciences*, 15 (1975): 67–114

Waerden, Bartel Leendert van der, *Science Awakening*, translated from the Dutch by Arnold Dresden, 2 vols, Groningen: Noordhoff, 1954–74; New York: Oxford University Press, 1961

Waerden, Bartel Leendert van der, *A History of Algebra: From al-Khwarīzmī to Emmy Noether*, New York: Springer, 1985

Whiteside, D.T. (ed.), *The Mathematical Papers of Isaac Newton*, vol. 5, Cambridge: Cambridge University Press, 1972

Wussing, Hans, *The Genesis of the Abstract Group Concept: A Contribution to the History of the Origin of Abstract Group Theory*, translated from the German by Abe Shenitzer, Cambridge, Massachusetts: MIT Press, 1984 (original edition, 1969)

Zaddach, Arno, *Grassmanns Algebra in der Geometrie*, Mannheim: Wissenschaftsverlag, 1994

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Scholars are divided on the issue of how to define algebra. The core concept is that of high school algebra, which teaches that the solutions of the equation $ax^2 + bx + c = 0$ are given by the formula $x = (-b \pm (b^2 - 4ac)^{1/2})/2a$ and that the equation $x^2 - a^2 = (x + a)(x - a)$ is an identity (true for all values of x and a). The use of letters for coefficients and unknowns, and of formal methods of deriving solutions, is characteristic of this form of algebra. For these reasons, MAHONEY argues that algebra did not exist before the 17th century. A less stringent view starts by observing that the word "algebra" derives from the Arabic *al-jabr* (meaning rearrangement), which appeared in the title of *al-Khwarīzmī*'s book on the solution of quadratic equations (written in the 9th century), and that it therefore makes sense to include Arabic work of this sort. The broadest view is that any organised approach to the solution of questions about numbers that includes the systematic derivation of answers deserves to be called algebra. On this basis, early Babylonian solutions to questions about sums of unknown numbers and their squares, which closely resemble how one calculates the above formula step by step, count as algebra. This is the view of most of the authors collected in SCHOLZ (although others might argue that this is the study of numbers and not algebra). In the opinion of most scholars of Greek mathematics, the best approach to the material is via some books of Euclid's *Elements*, while Apollonius' *Conics* is as an account of algebraic identities proved geometrically, and for this reason they speak of Greek geometrical algebra, a term first coined by ZEUTHEN. A stern, if not always persuasive, study of this subject is UNGURU, who argues that this material is geometry and is travestied by translation into algebra.

A number of books and articles present the factual basis for engaging with the history of algebra. Greek geometrical algebra is described in WAERDEN (1961), while WAERDEN (1985) takes the story from *al-Khwarīzmī* to his own time. BERGGREN describes Arabic work within the context of Islamic mathematics as a whole, while the articles in Scholz cover Greek, Arabic, and early modern algebra, and also describe the work of Doiphantus, algebra as applied to geometry, algebra and probability theory, algebraic number theory, and the rise of modern structural algebra. RASHED has written on other aspects of Islamic mathematics, especially the later algebraists.

More detailed studies include rival accounts of the work of Diophantus that draw on recently-discovered Arabic translations of lost Greek originals by RASHED and by SESIANO. The *Arithmetica* of Jordanus de Nemore, who was active in the early 13th century, was the standard source for theoretical arithmetic in the European Middle Ages; it is described in detail in the edition by BUSARD. The medieval algebraists or cossists (so-called because their name for the unknown was the "cosa" or thing) are described in specialist monographs, for which FOLKERTS may serve as an introduction. KLEIN remains a more provocative work, arguing that the decisive move in the creation of modern algebra was taken by Vieta, on the basis of an incorrect reconstruction of Greek ideas that found a common approach to the work of Apollonius and Diophantus. Historical scholarship on Descartes was revitalised by BOS, who showed in detail just how important geometry was in *La Géométrie*, a work too often seen as simply the start of modern algebra. Literature in the philosophy of mathematics and the history of science has yet to grapple with the weight of Bos's account. For Newton's ideas on algebra and their impact, the starting point is WHITESIDE's monumental eight-volume edition of his work, especially volume 5.

Starting in the 19th century, algebra grew from its roots in the study of number-like objects. A useful overview is that by NOVY. An important breakthrough came with Hamilton's proposition of a system of "numbers" generalising the complex numbers, but at the price of abandoning the commutativity of multiplication. Whereas hitherto it had been assumed that $ab = ba$, this is not true of Hamilton's quaternions, and from their introduction (in 1843) two currents gradually diverged. One, described by CROWE, led to the modern use of vectors, especially in physics. (A recent account of the emergence of the concept of a vector space is MOORE in *Historia Mathematica*.) The other led to other systems of hypercomplex numbers (objects one can add, subtract, multiply together, and multiply by real numbers), later called algebra. At this point the subject of algebra, as a university topic, became the new structural analysis of these formal systems. A pioneer, neglected in his lifetime, was GRASSMANN, whose work is discussed by Crowe, and in more detail by ZADDACH. As such it now includes the theory of groups, the origins of which are thoroughly described by WUSSING. The history of the field concept (where the four arithmetical operations are permitted) includes generalisations of the real numbers, which led mathematicians into logic and model theory, as carefully described by SINACEUR.

The view of algebra in particular, and all pure mathematics more generally, as structural acquired widespread currency with its acceptance by Piaget (on which he based his analysis of the child's learning of mathematics), and with the "new mathematics" in the 1960s, which was allegedly also a response to the unexpected Russian lead in the space race. Key texts are the works of Emmy Noether and her school, widely disseminated as German mathematicians fled the Nazis, and that of Bourbaki, a French collective of mathematicians that began with the aim of helping French mathematicians to catch up with their German colleagues in the 1930s. The real difficulties in the mathematics has delayed the presentation of any kind of history of these 20th-century developments, but BEAULIEU considers the early days of Bourbaki and CORRY makes a broader investigation of the structural movement. The traditional view of the mathematician on the history is given in the cited article by BIRKHOFF.

JEREMY GRAY

See also Geometry

Alienation

Feuer, Lewis S., "What is Alienation? The Career of a Concept", in *Marx and The Intellectuals: A Set of Post-Ideological Essays*, New York: Anchor Books, 1969

Geyer, R. Felix and David Schweitzer (eds), *Alienation: Problems of Meaning, Theory and Method*, London: Routledge and Kegan Paul, 1981

Israel, Joachim, *Alienation from Marx to Modern Sociology: A Macrosociological Analysis*, Boston: Allyn and Bacon, 1971

Kaplan, Morton A., *Alienation and Identification*, New York: Free Press, 1976

Meszaros, Istvan, *Marx's Theory of Alienation*, London: Merlin Press, 1970; New York: Harper and Row, 1972

Mouledoux, Joseph C. and Elizabeth C. Mouledoux, *Alienation: A Critical Evaluation of Selected Empirical Studies*, Montreal: Canadian Sociology and Anthropology Association, 1975

Ollman, Bertell, *Alienation: Marx's Conception of Man in Capitalist Society*, Cambridge: Cambridge University Press, 1971; 2nd edition, 1976

Rotenstreich, Nathan, *Alienation: The Concept and Its Reception*, Leiden: E.J. Brill, 1989

Schacht, Richard, *Alienation*, with an introduction by Walter Kaufmann, New York: Doubleday, 1970; London: Allen and Unwin, 1971

Schmitt, Richard and Thomas E. Moody (eds), *Alienation and Social Criticism*, Atlantic Highlands, New Jersey: Humanities Press, 1994

Torrance, John, *Estrangement, Alienation and Exploitation: A Sociological Approach to Historical Materialism*, New York: Columbia University Press, and London: Macmillan, 1977

For four decades social scientists have debated the meaning of the concept of alienation and its potential for fruitful empirical analysis. The denotations of alienation as an historical, philosophical or theoretical phenomenon, or as a psychological variable to be operationalized, were heatedly disputed in the decades of Marxism's hegemony in Eastern Europe, and thus the problem of alienation is fundamental to discourses on the human experience of socialist and capitalist societies in the 20th century. In sociology and social philosophy, the fate of the concept of alienation has been inexorably linked to the question of philosophical continuity in the thought of Karl Marx, and much of the difficulty with the concept has related to deficiencies of conceptual clarity and specificity. Any theory of alienation involves assumptions about human nature and the relationship between the individual and society, and generally emphasizes society (socio–economic contexts) or the individual (psychological experience). Marx's definition of alienation refers to the exteriorization of work and/or human activity and its products or results – that is, a loss of personal control, and therefore a consequent absence of meaning, power, and self-fulfilment. Estrangement from others and from nature are further manifestations of alienation.

FEUER maintains that alienation has become the "key ethical concept" of the age. Its resurgence was based on a revival of the early writings of Marx, specifically the *Economic and Philosophic Manuscripts of 1844*, in which Marx had developed a theory of alienation. Feuer claims that the concept was associated particularly with sexual alienation, as reflected in the early romantic thinking of Marx, and that Marx and Engels later replaced the concept with "exploitation". Feuer identifies six sociological modes of alienation, a phenomenon he claims as historically universal, and not in itself unique to modern class society. He considers the contemporary concept, "a concept of political theology", conveying a "mood of pervasive tragedy" and reflecting the self-alienation of the intellectual.

MESZAROS provides a clear examination of the Marxian meaning and usage of alienation. He explains the genesis and structure of Marx's theory of alienation including its economic, political, ontological–moral, and aesthetic aspects. With careful detail and precise use of Marx's German texts, Meszaros builds the evidence for the centrality and continuity of the theory of alienation within Marx's corpus. He deals with the controversy over Marx's concept, the problem of the individual in capitalist society, and finally the resolution of alienation in modernity through education. Within the Marxian context alienation is a concept of critique.

OLLMAN presents Marx's theory of alienation as contained in the *Economic and Philosophic Manuscripts of 1844* in relation to his conception of human nature, the four "relations" of alienation, and the labour theory of value in particular. In Ollman's perspective these relations of alienation are understood in combination with the theory of value in order to constitute "a useful aid for understanding capitalism . . . for those who share with Marx certain basic beliefs" – i.e. those, who see the ubiquity of alienated relations throughout capitalist society.

SCHACHT, in his 1970 exposition on alienation, attempts to clarify the origins of the concept and its philosophical, psychological and literary usage, and identifies basic contemporary issues of self and society deriving from the implications of alienation. Walter Kaufmann's introduction reminds us that "alienation is a central feature of human existence". Not wishing to discard the concept or ignore its realities, Schacht suggests a number of "issues" represented in the writings on alienation that lie somewhere between empirical propositions and philosophical assertions, but which are disappointingly obvious.

In an attempt to examine closely Marx's fundamental concepts of estrangement, alienation and exploitation, TORRANCE explores their potential as sociological concepts and their clarification in terms of property and class relations. The analysis is successful in demonstrating the heuristic possibilities of Marxian theory for identifying and understanding social and economic problems within contemporary society.

Particularly helpful in understanding the historical context of the concept and analysis of alienation within the discipline of sociology is ISRAEL's exploration of alienation in the theoretical writings of Marx, Weber, Simmel, and Durkheim. This work traces the analysis of alienation in theory and in applied research in macrosociology, social psychology and empirical sociology, and explores alienation's manifestations in the Soviet Union and Cuba. Israel maintains that a sociological understanding of alienation requires a shift, found even in Marx, from alienation to reification, "a process in which social relations gain the character of relations between things" and where social institutions gain independent powers over the members of society.

Attempts at operationalizing alienation in order to measure types and degrees among various groups and populations have been problematic, as a result of the use of mundane indicators

and meagre, often inconsistent, theoretical frameworks. The leading empirical studies of alienation are critically reviewed in MOULEDOUX & MOULEDOUX, a rare work of this genre, which meticulously examines the quantitative and qualitative difficulties of the research, especially those generated by ahistorical, reductionist approaches. The authors conclude that, given the unsatisfactory quality of empirical studies of alienation, on the one hand, and the overly generalized views leading to "speculative conceptions of what man and society might become given the realization of a particular 'theory'", on the other, the concept of alienation offers little hope or help in understanding the human condition.

KAPLAN addresses some of the fundamental theoretical problems and inconsistencies in Marx's analyses of alienation, and maintains that alienation as a concept must be separated from ideology and understood as "a practical problem that requires different practical solutions at different times". To address and reduce alienation in these terms requires linking it, Kaplan claims, to identification – i.e. to a sense of membership in human groupings and to a constructive personal history.

In a more philosophical discussion, ROTENSTREICH traces the development and reception of the concept of alienation in its Hegelian and Marxian usage, particularly within the historical and economic domains. Moving to the personal realm, he maintains that alienation is an inevitable dimension of processes (even dialectics) of identity and creativity within the individual. The limited impact of the concept of alienation, related as it was to the Marxian critique of structures, may have spelled its own obsolescence.

Reflections on the theoretical and methodological complexities of the concept of alienation in sociology can be found in the collection edited by GEYER & SCHWEITZER. Here, analyses of conceptual and methodological problems stand alongside attempts to produce formal theories of alienation. The variety of cultural contexts and approaches of such work illuminate the controversial dimensions of the concept.

In a selection of previously published radical writings that consider human alienation in specific experiential contexts, SCHMITT & MOODY provide recent and sociologically-provocative considerations of alienation. The contexts of alienation considered here include work, gender, race, disability, old age, nature, and the relation of the individual to society. Alienation is used to refer to a range of human problems and their consequences, such as lack of autonomy, isolation, and discrimination. The volume is based on the contention that "alienation is indispensable for describing accurately the condition of oppressed groups in our society". Alienation may be observed and understood most meaningfully through such a spectrum of human experiences.

SUSAN HOECKER-DRYSDALE

See also Capitalism and Science; Marx; Marxism and Science; Sociology

Almanacs

Bosanquet, Eustace F., *English Printed Almanacs and Prognostications: A Bibliographical History to the Year 1600*, London: Chiswick Press, 1917

Capp, Bernard, *Astrology and the Popular Press: English Almanacs 1500–1800*, London: Faber and Faber, and Ithaca, New York: Cornell University Press, 1979

Drake, Milton (ed.), *Almanacs of the United States*, 2 vols, Metuchen, New Jersey: Scarecrow Press, 1962

Kelly, John T., *Practical Astronomy during the Seventeenth Century: A Study of Almanac-Makers in America and England*, New York: Garland, 1991

Perkins, Maureen, *Visions of the Future: Almanacs, Time and Cultural Change 1775–1870*, Oxford: Clarendon Press, and New York: Oxford University Press, 1996

Sommerfeldt, W.P. (ed.), *Den norske almanakk gjennom 300 år 1644–1944*, Oslo: Universitetets almanakkforlag, 1944

Stowell, Marion Barber, *Early American Almanacs: The Colonial Weekday Bible*, New York: Franklin, 1977

Originating in Europe in the 14th century, the almanac rapidly evolved from a relatively primitive form into a calendar or ephemeris in which were noted the positions of the heavenly bodies for regular intervals or specific dates. Additional information provided in almanacs has always been extremely diverse, and has included the times of the rising and setting of the sun, moon and certain stars, eclipses and conjunctions, weather forecasts, astrological predictions, days of historic and religious significance, medical advice, monetary tables, tide tables, tables of distances between towns and cities, literary contributions, and a wealth of other material. The relative emphasis of these different elements has also changed greatly over time. Following the introduction of printing, almanacs became extremely widespread, with print runs in the thousands by the 17th century. This can be explained in part by their practical domestic use; for instance, prior to the wide availability of clocks, almanacs could be used as a means of telling the time, while the weather forecasts that they usually contained were of vital importance in agriculturally-based communities, and the calendar could be used as a diary.

Much that has been written on the history of almanacs has tended to concentrate on those produced in particular countries. It is therefore quite easy to find studies for individual countries, but more difficult to find secondary sources that give a more general account. BOSANQUET provides, for instance, a survey of almanacs published in England up to 1600. The bulk of the work is a chronological listing of the almanacs published, with a short description of each, although the introduction includes a brief history of almanacs. DRAKE provides a similar resource for American almanacs for the period 1639–1850.

STOWELL, as the title indicates, underlines the huge cultural impact of the American almanac, given that, apart from the Bible, it was generally the only written material available in American homes. She chronicles the development of almanacs and their contents from the 17th century onwards, but with emphasis on the 18th century. Describing the main families publishing almanacs, such as the Ames and the Franklins, she also analyses the almanac as literature, paying particular attention to the expectations of the readership.

CAPP, again dealing largely with England, provides two main narratives. First, he uses an investigation of English almanacs to trace the development of astrology between 1500 and 1800.

Second, by analysing the range of subjects covered in almanacs, he attempts to explore the interests, attitudes, and needs of the English lower classes. Consequently, he includes sections on politics, society, religion, science and medicine, and history and literature, as well as tracing the general development of the almanac throughout the period. The author thus demonstrates how English almanac-makers advanced the practice of astrology at the popular level (which complemented the work of astrological consultants), while illustrating in addition the wide range of needs that almanacs fulfilled. This included, for example, giving advice on farming, news of highways and fairs, medical and sexual advice, tables of weights and measures and of interest and excise rates, popular science, and navigational aids. Furthermore, the book contains excellent appendices, listing not only all of the almanacs currently known to have been published in the period (with locations for extant editions), but also a list of their dedications and short biographical entries on each almanac author.

PERKINS extends chronologically the story developed by Capp and deals with almanacs in both England and Australia. Her central thesis is that the period 1775–1870 witnessed several important changes. First, astrology and prophecy gradually disappeared from the almanac, principally as a result of Whig reform of popular culture and the promotion of science. Second, new forms appeared, in particular the statistical almanac. Last, the traditional almanac declined in popularity, as a result of changing perceptions of the nature of time and the appropriation of many of its functions, such as weather forecasting, by other media, notably newspapers.

Despite the apparent limits implied by the title, KELLY provides an account that covers the development of the almanac from its origins in Europe in the 14th and 15th centuries, through England in the 16th and 17th centuries, to America during the colonial period. Concentrating on the technical aspects of production, the story begins with almanac-making, which required only a basic knowledge of arithmetic, geometry and astronomy, with the almanacs used for applications in astronomy, astrology and navigation. The account culminates in the production of national ephemerides, such as the Nautical Almanac, published in England from the 1760s, and the American ephemeris and nautical almanac, produced from 1852, by which time the emphasis was on the navigational applications of the astronomical information contained in these publications. This evolution, argues Kelly, reflected an increasingly sophisticated approach to computational astronomy, which was closely associated with the advancement of observational astronomy. Kelly's emphasis is on an analysis of the astronomical data used in the preparation of almanacs, and he adopts a comparative approach in order to demonstrate the dependence of American almanac-makers for their astronomical data on English ephemerides and planetary tables.

SOMMERFELDT contains essays on various aspects of Norwegian almanacs, with titles such as weather, medicine, astrology, prognostication and the role of time in social life. It also lists Norwegian almanacs and navigational calendars throughout history and includes a register of topics covered in almanacs of that country.

RICHARD DUNN

Anatomy

Choulant, Ludwig, *History and Bibliography of Anatomic Illustration*, edited and translated from the German by Mortimer Frank, New York: Schuman, 1945 (original edition, 1852)

Cole, F.J., *A History of Comparative Anatomy: From Aristotle to the Eighteenth Century*, London: Macmillan, 1944; reprinted, New York: Dover, 1975

French, Roger, "The Anatomical Tradition", in *Companion Encyclopedia of the History of Medicine*, vol. 1, London and New York: Routledge, 1994

Lind, L.R., *Studies in Pre-Vesalian Anatomy: Biography, Translations, Documents*, Philadelphia: American Philosophical Society, 1975

O'Malley, Charles D., *Andreas Vesalius of Brussels, 1514–1564*, Berkeley: University of California Press, 1964

Richardson, Ruth, *Death, Dissection, and the Destitute*, London and New York: Routledge and Kegan Paul, 1987

Roberts, K.B. and J.D.W. Tomlinson, *The Fabric of the Body: European Traditions of Anatomical Illustration*, Oxford: Clarendon Press, and New York: Oxford University Press, 1992

Singer, Charles, *The Evolution of Anatomy: A Short History of Anatomical and Physiological Discovery to Harvey*, New York: Knopf, and London: Kegan Paul Trench and Trubner, 1925; revised edition as *A Short History of Anatomy from the Greeks to Harvey*, New York: Dover, 1957

Both Charles Singer and F.J. Cole provide concise, readable surveys of the history of anatomy in Western society. SINGER is divided equally between the Greeks, the "Dark Ages", the Middle Ages and Renaissance, the era of William Harvey, and modern times. Profusely illustrated with the standard historical representations of anatomy, Singer's work explicitly makes no distinction between form and function. COLE provides a concise overview of "zootomy" from ancient Greece to the 16th century. Zootomy is defined as the pursuit of animal dissection to the point of indivisibility: i.e. animals were "resolved into their smallest parts". Animals have long been studied both for information about the specific animal's structure and to extrapolate those findings to the structure and working of humans. Cole explains that the homologies between "lower" animals and man have occupied the minds of many scientists and historians, particularly after the theory of evolution became more widely known. Cole discusses the "craft" of anatomy and the encyclopaedic compilations of comparative anatomy in the Renaissance. He proceeds to distinguish these contributions from the later "analysts" of anatomy, beginning with Marcello Malpighi. The Dutch contributions of Antoni van Leeuwenhoek, Jan Swammerdam, and Frederik Ruysch are discussed, as are the changing aspects of teaching anatomy to natural philosophers and artists since the Renaissance.

LIND examines the politico–cultural background of medieval scholasticism and Renaissance humanism before providing extensive "life and work" surveys of seven individuals who

made significant contributions to anatomy between 1490 and 1543. Lind provides biographical sketches of Alessandro Achillini, Alessandro Benedetti, Gabriele Zerbi, Berengario de Carpi, Niccolo Massa, Andres de Laguna, Johannes Dryander, and Giovanni Battista Canano.

During the same year in which Copernicus' influential cosmological writing appeared and began to alter the macrocosmic way of seeing the universe, Vesalius published *De humani corporis fabrica* (1543), which began to shake Aristotelian microcosmic understandings of the human body. O'MALLEY provides the most complete investigation in English of the author and his work, arguably the most significant in the history of Western anatomy.

Procuring "specimens" for anatomical dissection has long vexed the educators of physicians. Surgeons also claimed that cadaveric human bodies were essential tools for improving their anatomical knowledge of the structures underlying the skin, as well as for practising their operative procedures. RICHARDSON provides an exhilarating account of the pinnacle of debate over the ownership of the body in her investigation of early 19th-century British medico–legal struggles. She discusses dissection as the ultimate fate of executed criminals, the frequent grave robbings, and the Anatomy Act of 1832, which legalized the procurement of the corpses of the poor, and in effect transferred the penalty of dissection from criminals to paupers.

Surgical treatises throughout history typically include an extensive section on anatomy. Anatomical knowledge was not only expected to be committed to memory, but put to practical use as well. Some historians have deemed that all improvements in the surgical art were solely due to advancements in anatomy. Gross anatomy – the structures visible at the dissection table – has recently been overshadowed by increasing interest in microscopic or cellular anatomy. The microscope distinctively changed the anatomical view of the body, but as FRENCH argues, the view of gross anatomical structures did not vanish into homogeneity. Rather, the diversity of structure was continued, even multiplied, at greater magnifications.

Anatomical writings are typically generously illustrated. CHOULANT analyzes the art and craftsmanship behind anatomical illustration as well as the graphic and plastic art forms. Brief attention is paid to pre-Vesalian art; instead, he concentrates his broad biographical and bibliographical coverage to post-Vesalian European anatomical illustration through the mid-19th century. This work focuses on human anatomy and the works which, through their lasting influence, are considered of key historical significance. ROBERTS & TOMLINSON review the same period as Choulant, though with less attention to detail, and then continue a discussion of European anatomical illustration through the 20th century.

PHILIP K. WILSON

Anthropology

Asad, Talal (ed.), *Anthropology and the Colonial Encounter*, New York: Humanities Press, 1993

De Waal Malefijt, Annemarie, *Images of Man: A History of Anthropological Thought*, New York: Knopf, 1974

Evans-Pritchard, E. E., *A History of Anthropological Thought*, edited by André Singer, London: Faber and Faber, and New York: Basic Books, 1981

Foucault, Michel, *The Order of Things: An Archaeology of the Human Sciences*, translated from the French by Alan Sheridan, London: Tavistock, and New York: Vintage, 1970 (original edition, 1966)

Goody, Jack, *The Expansive Moment: The Rise of Social Anthropology in Britain and Africa, 1918–1970*, Cambridge and New York: Cambridge University Press, 1995

Gould, Stephen Jay, *The Mismeasure of Man*, New York: Norton, 1981; revised and expanded edition, 1996

Haraway, Donna, *Primate Visions: Gender, Race, and Nature in the World of Modern Science*, New York: Routledge, 1989

Harris, Marvin, *The Rise of Anthropological Theory: A History of Theories of Culture*, New York: Crowell, and London: Routledge and Kegan Paul, 1968

Herbert, Christopher, *Culture and Anomie: Ethnographic Imagination in the Nineteenth Century*, Chicago: University of Chicago Press, 1991

Holmes, Lowell D., *Quest for the Real Samoa: The Mead/Freeman Controversy and Beyond*, South Hadley, Massachusetts: Bergin and Garvey, 1987

Honigmann, John J., *The Development of Anthropological Ideas*, Homewood, Illinois: Dorsey Press, 1976

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Anthropologists have a deep-rooted interest in the history of their discipline, perhaps in part because, faced with its fragmentation into various subdivisions and schools, history offers some coherence and stability. Departments of anthropology have their own required course in the history of the discipline with related textbooks and monographs, written mainly by anthropologists for anthropologists. These histories have two aims in common: to teach anthropology through a historical survey, and to provide polemical tools in the fight against rival programs. In the main, these functional histories have presented the history of anthropology as primarily a history of ideas in the "western" tradition. Historical bones to pick remain almost entirely internal, jointed by presentist pursuits.

A fine example of the textbook tradition, HONIGMANN presents the history of anthropology as a history of Western civilisation, from the creation of the science of "Man" by the Greeks and Romans, through the Middle Ages and the Renaissance, to the formative debates over "diffusionism" and "evolutionism" of the 19th and 20th centuries. DE WAAL MALEFIJT is another example along these lines. LEAF adopts a more philosophical viewpoint, presenting the history of anthropology as a history of underlying philosophical assumptions regarding the nature of man, mind and science, which reveal two major philosophical trends: "monism" and "dualism". Leaf's terms are rather idiosyncratic to say the least ("monism" here means a belief exclusively in the world of appearances), and he settles on the monistic view as the saviour of modern anthropology.

FOUCAULT radically challenges this "grand river" (or evolutionary) view of history and finds the science of man a rather recent discovery, enclosed in an episteme, bound on both sides, and doomed to pass away in the late modern period. Foucault moves away from the human subject as nodal in the history of anthropology, and finds wider morphological similarities between the sciences of man, linguistics, and the political economy of post-Enlightenment Europe.

Of prime concern to the textbook tradition is the supposed "revolution" (see JARVIE) in anthropology that took place in the early decades of the 20th century. From this point on, evolutionary accounts of human nature were replaced by functionalist and "diffusionist" accounts of culture, which were less concerned with tracing developments and classifications according to the degree of "primitive". The last detailed historical work from the early "evolutionist" school is PENNIMAN. Unluckily, just as the "functionalist school" was declaring evolutionism a dead letter in the 1930s, Penniman, curator of the Pitt–Rivers Museum in Oxford, linked the beginnings of modern anthropology with the biological revolution activated by Darwin's *Origin of Species*. Thus, Penniman's history was considered outdated at publication. Nevertheless, his work is still one of the best accounts of the emphasis on technology in late 19th-century anthropology – a subject often passed over by later historians. Subsequent editions of the work were increasingly concerned with the desperate attempt to reinstate Darwin's biological revolution at the centre of the history of anthropology in the face of the functionalist onslaught.

The founders of the "social anthropology" school at Oxford had their own view of the history of their subject. In a collection of lectures delivered by one of the patrons of the modern "diffusionist" school at the Institute of Social Anthropology, Oxford, EVANS-PRITCHARD related biographical stories of the "greats" of anthropology from Montesquieu to Robert Herz. These biographies were highly personal and intended to relay a sophisticated moral tale of the rise of the functionalist school. Following Evans-Pritchard, much of the history of anthropology has been told through biographies of the greats, one of the best examples being that on Franz Boas by HYATT.

In the main, histories since Penniman have stressed the progressive dissolution of the hegemony of evolutionism, its supposed racism, and its "acorn to oak" (to use Ernst Gellner's borrowing of a Hegelian term) view of necessary cultural development. LOWIE was first off the mark. As an early advocate of the "ethnographic turn", Lowie used his history to rage against evolution in favour of the diffusionist view of culture. As Darwin was jettisoned, the German/American anthropologist and founder of "cultural anthropology", Franz Boas, was made the hero of this story.

HARRIS marks a late and powerful reaction against this anti-evolutionism in the historiography of anthropology. In his massive, rollicking polemic against relativists, structuralists, and idealists of every kind, Harris spares no one the blame for the disintegration of the field: the French, structuralists, inductivists, and neo-Kantians are all responsible for turning anthropology from the "natural", while Boas is a "politically motivated" obscurantist. All this is done with consummate skill and remarkable historical rigour, making Harris's work the controversial standard for a number of years. His aim was to resurrect a form of "cultural materialism", later elaborated in his book by that title, which is a hybrid sort of materialism – an uneasy synthesis of Malthus and Marx, which constitutes a step beyond "cultural idealism" and owed much to the "hydraulic thesis" of Karl Wittfogel. Not surprisingly, Harris's detailed history culminates with Wittfogel and his hydraulic materialism as the modern defender of science against obscurantism. Harris thus sits happily within the history of ideas tradition, as he details the triumph of materialism and science over mysticism and idealism. Interestingly, however, his own theory of "cultural materialism" seems to point in a different direction, towards embedded practices and material grounds for belief, although there is little of this present in his history.

George Stocking is the exception to the rule regarding anthropologists writing their own history in reverse. Although trained as an anthropologist, Stocking is a one-man industry in the professional history of anthropology, from his editing of the exemplary University of Wisconsin series on the history of anthropology to his monographs on the history of modern, mainly British, anthropology.

STOCKING (1968), essentially a collection of essays, introduced a cautious yet powerful critique of the "presentism" of

the field, taken from the then-fashionable "paradigmatic" approach of Thomas Kuhn. Stocking transcended the polemics of Harris and Lowie in order to regard the wider context of the history of modern anthropology, in which we find Boas reading Kant in German in the hope of finding a science of culture, we discover the persistence of the race problem in a growing liberal democracy, and we lay bare the institutional roots of a growing professionalism. Stocking uses his remarkable familiarity with archival and public texts to write a wholly interdisciplinary history of the field, although paradigms are soon lost and the early Stocking settles down to a history of ideas approach. In his account, the "race" concept looms over 19th-century debates concerning culture and peoples, and as he traces the rise of the competing "culture" concept in the gentle relativism of Boas and his school, it is very clear (for all his anti-presentism) where Stocking stands on the debate. None the less, he is extremely careful to illuminate the subtleties of the divisions over race, evolution and culture, and overdue distinctions are made between "evolutionist" and "racist", polygenist and monogenist, Darwinist and Lamarckian. Stocking also takes care to avoid a sort of conceptual whiggism: the culture concept means something quite different to Boas than to modern cultural anthropologists.

In STOCKING (1987) the focus is narrowed to Victorian anthropology, and here Stocking is more careful to attend to the narrative and institutional grounds in his historical account of the rise of anthropology. Race still looms large as Stocking concentrates on the effects of the "Darwinian Revolution"; while race is surely tied to evolutionism, he is careful to point out that evolutionism did not lead necessarily to racism. Indeed, Stocking sees liberal Darwinians as a bulwark against the rising racism of the structural anthropology school, and he follows the institutional wranglings of the competing anthropological societies. Stocking resurrects the Oxford anthropologist, Edward Tylor, as a pivotal figure, both as a follower of the Darwinian tradition and as the dominant player in the professionalization of the field. He explores the involvement of anthropologists in the imperial project and in the moderation of that project through groups such as the "protection of aborigines" movement. (Unfortunately, in this work "Victorian Anthropology" means Victorian England). In a lengthy and learned conclusion, he expands on the methodological problems involved in writing a history of anthropology, while steering a course between historicism and essentialism.

In his latest work, STOCKING (1996), he retraces the final steps in the professionalization and institutionalization of the field in England. Here Stocking draws on an increasingly "network" oriented historiography; the very success of institutionalization is intimately related to its ability to link up with other activities of much more acknowledged status – namely, the curation of collections of archaeological and ethnographic material, the study of the origin and development of religion, and the utilitarian needs of colonial administration. Stocking again de-emphasises the role of the idea of functionalism in the school of Malinowski, and offers instead an examination of the structures of professionalization and institutional grounding. But, in this, Stocking has narrowed his vision; wider questions of cultural context seem to evaporate, except insofar as they are immediately encompassed within the network of anthropological actors, and the history becomes progressively internalised.

KUPER also downplays the role of functionalism in the struggle of Malinowski's school against Victorian and Edwardian evolutionism. In Kuper's view, rising accumulation and field studies put paid to the kind of "armchair" anthropologising preferred by the 19th-century evolutionists. Kuper, like Harris, carves his history with a sharp polemical edge, and is especially brutal to the French structuralists and their Anglo-American followers. Taking a more social turn, URRY fills in some of the gaps between Stocking and Kuper.

As sociobiology thrust biologism back into anthropological debate in the 1970s, it is not surprising that historiographical controversy soon followed. GOULD's penetrating historical survey of the attempts by structural anthropologists and anthropometricists to measure racial, class and sexual difference was meant primarily as a first line of defence against this biological turn. The second edition appends a long attack on the recent attempt to "Bell curve" the concept of race. With this moral lesson foremost, much of the history gets compressed and even skewed, as the subtleties of the wider history of physical anthropology get lost in the telling. While this is certainly not pure contextualism, Gould still represents one of the best accounts of the French and American schools of measurement. For older pre-Darwinian ideas of race in anthropology, see the classic study by STANTON.

The "sociobiological turn" of the late 1970s inspired a furious debate over the historical worth of the main studies of the cultural school – mainly Margaret Mead's germinal work, *Coming of Age in Samoa* (1928). Freeman led a brutal historiographical cavalry charge against Mead in favour of sociobiology, and the cultural anthropologists fought back with their own histories and polemics. Some aspects of this debate can be found in HOLMES.

These historical debates still leave us at the level of the history of ideas, as they are remarkably unanthropological in their approach to the origins of ideas. GOODY is one dissenter, who writes as a participant observer in the process. Taking a cue from the functional trend in social anthropology, of which he was a main player, Goody's history traces the interactions between anthropological institutions and the intellectual life that exists within them, is constructed by them and, in turn, creates them. Goody recognises the internalism of the field and attributes the rise of Malinowski and his school to an institution-building that has internalised the scope of anthropology and declared as invalid questions asked by outsiders such as "Marxists, Weberians, sociologists and the public at large". Goody immerses himself in this internalisation and his history is very autobiographical. He is harshly critical of recent equations of anthropology with the imperialist project, and devotes a considerable part of his history to a polemic against KUKLICK, who sees the imperial anthropologists as necessarily "solipsists", imposing themselves and their "eurocentric" concerns on anthropological subjects. Goody feels that the story is much more complicated, indeed much more internal, than that.

Kuklick adapts many tools of recent Marxist criticism to her history in order to present anthropology as immersed in the ideological and utilitarian concerns of colonial Europe. In her final chapter, she shows a concern for the history of local knowledge, and for the involvement of the subject in the history of anthropology. That said, her subjects are given little voice, and end up as passive receptors in the colonial exercise.

HERBERT, in contrast, takes a postmodern approach. Opening a toolbox containing a jumble of Derrida, Foucault, Lacan, and so on, Herbert follows ethnographic imagery well beyond the confines of internal anthropological debates. He develops a "cultural studies" approach to the culture concept itself, following ethnographic imagery into missionary fieldwork in Polynesia, Mayhew's excursions in East London, and the novels of Trollope. He claims that the idea of culture, and indeed much of modern anthropology, was an ambiguous and sublimated response to the original-sin theology of John Wesley. Here we see a study of the place of anthropology that is reflexive, using anthropological and literary understandings of culture to study anthropology itself. However, Herbert still circles around one concept – culture – and his work would still settle comfortably into a history of ideas format.

Anthropology has recently discovered the problems of reflexivity, and the interaction of the anthropologist and his subject in the creation of beliefs and institutions. The role of the subject is beginning to be explored in the history of anthropology, as can be seen in Kuklick and others. PAYDEN has recovered the role of the American Indian in the move away from Enlightenment discourse on "human nature" towards the empirical study and historical relativism of 19th-century anthropology. The papers in ASAD begin an exploration into stories of the "anthropologised" in a colonial situation, while HARAWAY, writing as an ethnomethodologist, has exposed the history of primate anthropology to a feminist, and at times postmodern, gaze.

To date, however, the voice of those studied by anthropology has yet to be heard. Most histories of anthropology remain traditional in their approach, while anthropology itself has been recently facing a crisis in "reflexivity". A reflexive anthropological history of anthropology has yet to be written.

GORDON MCOUAT

See also Prehistory: archaeology and anthropology

Anthropometry

Barkan, Elazar, *The Retreat of Scientific Racism: Changing Concepts of Race in Britain and the United States Between the World Wars*, Cambridge and New York: Cambridge University Press, 1993

Bowler, Peter J., *Theories of Human Evolution: A Century of Debate, 1855–1944*, Baltimore: Johns Hopkins University Press, 1986

Gould, Stephen Jay, *The Mismeasure of Man*, New York: Norton, 1981; revised and expanded edition, 1996

Greenwood, Davydd J., *The Taming of Evolution: The Persistence of Nonevolutionary Views in the Study of Humans*, Ithaca, New York: Cornell University Press, 1984

Haraway, Donna, *Primate Visions: Gender, Race, and Nature in the World of Modern Science*, New York: Routledge, 1989

Hoyme, Lucile E., "Anthropology and Its Instruments: An Historical Study", *Southwestern Journal of Anthropology*, 9 (1953): 408–30

Hrdlicka, Ales, "Physical Anthropology: Its Scope and Aims; Its History and Present Status in America", *American Journal of Physical Anthropology*, 1/1 (1918): 3–23

Hughes, Miranda, "The Dynamometer and the Diemenese", in *Experimental Inquiries: Historical, Philosophical, and Social Studies of Experimentation in Science*, edited by Homer E. Le Grand, Dordrecht: Kluwer Academic, 1990, 81–98

Mann, Gunter and Franz Dumont (eds), *Die Natur des Menschen: Probleme der physischen Anthropologie und Rassenkunde, 1750–1850*, Stuttgart: Fischer, 1990

Schiebinger, Londa, *Nature's Body: Gender in the Making of Modern Science*, Boston: Beacon Press, 1993

Stanton, William, *The Leopard's Spots: Scientific Attitudes Toward Race in America, 1815–1859*, Chicago: University of Chicago Press, 1960

Stepan, Nancy, *The Idea of Race in Science: Great Britain, 1800–1960*, Hamden, Connecticut: Archon Books, and London: Macmillan, 1982

Very few studies exclusively devoted to anthropometry exist in the history of science. Broadly construed, the subject includes the use of various instruments to measure every facet of the human body, as well as experiment and statistical calculus. Practitioner accounts reveal the broad number of disciplines from which anthropometry can claim founders. HRDLICKA traces anthropometry back to the 17th century, pointing to Edward Tyson, Linnaeus, Buffon, George Cuvier, Johann Friedrich Blumenbach, Samuel Thomas Soemmering and others for the discipline's origin. The best historical account of anthropometric instruments is still the brief article by HOYME, who catalogues the principle instruments beginning in the 17th century. She describes their development, includes numerous illustrations, and uses this material culture to analyze how practitioners generated their hypotheses and theories.

Discussions of anthropometry appear in some of the classic studies in the science versus religion debate, especially in the history of evolutionary theory. STANTON's well-known study of race science in early 19th-century America remains the most relevant contribution. His work contextualizes American anthropometry in the development of European physical anthropology, and his analysis of the "misdirection" of research due to cultural factors resonates well with current historiographic trends. He analyzes the intersection of physical anthropology with evolutionary theory, religious debate, and the question of race. His argument that jousts with religious leaders kept American researchers from proceeding in an evolutionary direction remains unchallenged by more recent research.

Anthropometry has had a more prominent place in histories of race science. STEPAN's history of racial notions in physical anthropology and biology is mainly focused on Britain from 1800 to 1960, but she traces American and European influences. She examines the uncertainty many practitioners felt about the meaning of their measurements in debates over human evolution and their tendency to maintain views of racial fixity. A number of valuable essays on anthropometry in general and the problem of race in particular have been gathered into a volume edited by MANN & DUMONT. The

authors have contributed important studies on key debates of the 18th and 19th-centuries in anthropometry including the interpretation of data, links with phrenology, and race. Kant, Herder, Buffon, Cuvier, Blumenbach, and Camper are all discussed, making this collection one of the most comprehensive examinations of the period in any language.

BARKAN compares late 19th- and 20th-century British and American research in biology and anthropology. He links theoretical debates with institutional and social developments and challenges the notion that the Holocaust was responsible for the decline of racial conceptions in science. Eugenics, genetics, and the rise of culture theory are all examined and Barkan develops an intriguing argument that "outsiders" (women, Jews, and "leftists") infused more egalitarian notions into science, which led to a fatal critique of race science.

Statistical analyses and bodily measures have been important in the development of the nature versus nurture controversy. GREENWOOD shows how anthropometric measures contributed to the persistence of non-evolutionary conceptions of human nature. He uses a generalized notion of humoral physiology as a foil to compare evolutionary and non-evolutionary views. His research reinforces points made in Stepan's book and provides an excellent, detailed discussion of anthropometry and the construction of racial and national characters. GOULD's *The Mismeasure of Man* is probably the most detailed study of anthropometric measures and biological determinism. Gould re-examined and replicated numerous anthropometric studies in areas ranging from craniometry to IQ testing, in an attempt to discredit arguments used by biological determinists and to show how *a priori* conceptions can influence the interpretation of data.

Anthropometry has also played an important role in the history of archaeology. BOWLER places archaeological and anthropometric work within the context of larger debates concerning human evolution. His summaries are the most technically proficient and comprehensive, though the book is difficult because it is organized by topic rather than chronologically, leaving the reader to form a comprehensive view.

Recent researchers have applied theories from the sociology of science, critical theory, and feminism to discuss anthropometry within a variety of new contexts. HUGHES uses a Latourian perspective to show how instruments could be used to enhance the credibility of expedition reports. One of the few current studies on 18th-century field experiments, it is a valuable history of the dynamometer and its role in strengthening the networks of knowledge and power. Historians examining sex and gender issues are also uncovering important evidence. SCHIEBINGER has a virtual monopoly on the 18th century with her exceptional analyses of anthropometric research on sex, race, and primatology. Her work includes discussions of important issues, including research on primate sexuality and the marginalization of women and non-white races. She successfully links these topics and shows how they fit with broader researches in comparative anatomy and natural history. HARAWAY's history of 20th-century primatology and physical anthropology combines the history of science with feminist and leftist critiques of both objectivity and the sociology of scientific knowledge. Most importantly, Haraway has gathered an impressive array of evidence, detailed analyses of texts, field research, and experimental research. Sometimes controversial, always engaging, Haraway and Schiebinger have both contributed important discussions on the permeable boundary between humans and apes, scientists and "others", without losing sight of specific researches or technical details.

BRAD D. HUME

See also Race

Anti-Vivisection

Cunningham, Andrew and Perry Williams (eds), *The Laboratory Revolution in Medicine*, Cambridge and New York: Cambridge University Press, 1992

French, Richard D., *Anti-Vivisection and Medical Science in Victorian Society*, Princeton, New Jersey: Princeton University Press, 1975

Jasper, James and Dorothy Nelkin, *The Animal Rights Crusade: The Growth of a Moral Protest*, New York: Free Press, 1992

Lederer, Susan E., *Subjected to Science: Human Experimentation in America Before the Second World War*, Baltimore: Johns Hopkins University Press, 1995

Ritvo, Harriet, *The Animal Estate: The English and Other Creatures in the Victorian Age*, Cambridge, Massachusetts: Harvard University Press, and Harmondsworth: Penguin, 1987

Rupke, Nicolaas A. (ed.), *Vivisection in Historical Perspective*, London and New York: Croom Helm, 1987

Ryder, Richard D., *Animal Revolution: Changing Attitudes Towards Speciesism*, Oxford and Cambridge, Massachusetts: Blackwell, 1989

Turner, James, *Reckoning with the Beast: Animals, Pain and Humanity in the Victorian Mind*, Baltimore: Johns Hopkins University Press, 1980

Opposition to scientific experiments on living non-human animals has as long a history as the practice itself; that is, it has existed at least since the classical Greek era. This opposition has been based on moral objections – to the allegedly deleterious impact of animal cruelty on humans; or to the apparent discounting of non-human animals' moral interests – and/or on critiques of the scientific utility of such experiments, said to arise from errors in extrapolating from one species to another, or from the mechanistic model of the human body that the experimental approach implies. The strength of such opposition has varied between countries and over time, as has historical interest. Not surprisingly, this historical interest has very often been the product of a prior commitment to the cause, just as serious consideration of the movement and its impact is generally absent from the historiography of biomedical and biological science.

An important exception is the volume of essays edited by RUPKE, the essential starting point for an overview of the history of the protest from antiquity to the 1970s, largely written from neutral perspectives. The essays cover the anti-vivisection movement in the United States, the United Kingdom and several European countries. Among the particular themes addressed are the role of women in the English protest and the response of British scientists to attack in the 1880s.

The most extensive body of historical research has focused on the late 19th and early 20th century in Britain. This was the place and time for very vigorous protest against what can now be seen as the laboratory revolution in medicine, and FRENCH's book on the British movement remains the central work. It considers the development and decline of the movement within the context of changes in science, in the medical profession and in attitudes to animals in the immediate post-Darwin period. His discussion of the significance of changes in public attitudes towards, and understanding of, science are relevant to debates in the 1990s. The collection edited by CUNNINGHAM & WILLIAMS provides the scientific context for the Victorian protest through detailed studies of laboratory practices and institutions. One essay (by Richards) specifically addresses the extent of suffering caused by late 19th-century animal experimentation and several other essays touch on the controversy. Turner and Ritvo both analyse changing attitudes and practices towards non-human animals in general in the Victorian period. TURNER focuses on conceptions of pain and suffering, and their implications for animal welfare campaigns in general, and for perceptions of alleged "scientific cruelty" in particular. RITVO describes the changing cultural significance of pets, wild animals and animal breeding in Britain. She analyses the function of animals as metaphors in Victorian society; for example, the ways in which they could symbolise class divisions. She argues that anti-vivisection offered a way in which troubled Victorians could reject modernist and materialist philosophies that valued progress (and hence science) above all else.

One of the long-standing claims of the anti-vivisection movement is that experimenting on animals places doctors at the top of a slippery slope towards experimenting on humans. The history of these claims and the relationship between human and animal experimentation and protests over it in the United States are discussed by LEDERER.

Not surprisingly, the upsurge of animal rights protests in many countries, particularly in the US and the UK, since the mid-1970s has stimulated fresh histories of the movement for animal protection in general, and also sociological interest in the present. Of the newer committed histories, that by RYDER, a leading English activist and originator of the term "speciesism", is one of the most comprehensive and accurate. Besides anti-vivisection, the course of protests against cruelty to farm animals and hunting are considered, mainly but not exclusively focused on Britain. JASPER & NELKIN present a similarly broad ranging analysis of the development of the American animal rights movement, including anti-vivisection protests, writing as academic sociologists but in a highly readable style. A brief historical overview is followed by detailed analysis of the different campaigns in the 1970s and 1980s.

M.A. ELSTON

See also Experimental Physiology

Arabic Science

Berggren, J.L., "History of Mathematics in the Islamic World: The Present State of the Art", *Bulletin of the Middle East Studies Association of North America*, 19 (1985): 9–33

Berggren, J.L., *Episodes in the Mathematics of Medieval Islam*, New York: Springer, 1986

D'Alverny, Marie-Thérèse, "Translations and Translators", in *Renaissance and Renewal in the Twelfth Century*, edited by Robert L. Benson and Giles Constable, Cambridge, Massachusetts: Harvard University Press, and Oxford: Clarendon Press, 1982

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Kennedy, Edward S. *et al.*, *Studies in the Islamic Exact Sciences*, Beirut: America University of Beirut Press, 1983

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Lindberg, David C., *Theories of Vision from al-Kindi to Kepler*, Chicago: University of Chicago Press, 1976

Lindberg, David C., "The Transmission of Greek and Arabic Learning to the West", in his *Science in the Middle Ages*, Chicago: University of Chicago Press, 1978

Nasr, Seyyed Hossein, *Science and Civilization in Islam*, Cambridge, Massachusetts: Harvard University Press, 1968; 2nd edition, Cambridge: Islamic Texts Society, 1987

Rosenthal, Franz, *The Classical Heritage in Islam*, translated from the German by Emile and Jenny Marmorstein, Berkeley: University of California, 1975; London: Routledge, 1992 (original edition, 1965)

Sabra, A.I., "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam: A Preliminary Statement", *History of Science*, 25 (1987): 223–43

Sabra, A.I., "Optics, Islamic", in *Dictionary of the Middle Ages*, edited by Joseph R. Strayer, vol. 9, New York: Scribner, 1987

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Sabra, A.I., "Introduction" to *The Optics of Ibn al-Haytham*, edited and translated by Sabra, London: Warburg Institute, 1989

Saliba, George, *A History of Arabic Astronomy: Planetary Theories During the Golden Age of Islam*, New York: New York University Press, 1994

Saunders, J.J., "The Problem of Islamic Decadence", *Journal of World History*, 17 (1963)

Sayili, Aydin, *The Observatory in Islam, and Its Place in the General History of the Observatory*, Ankara: Türk Tarih Kurumu Busimevi (Turkish Historical Society Publication), 1960; New York: Arno Press, 1981

The term "Arabic science" is used here to denote the corpus of scientific knowledge that originated with the spread of Islam and the Arabic language throughout the Middle East towards

the middle of the 8th century. The great bulk of that knowledge was recorded in Arabic, with later contributions in Persian. While many of the early translators and contributors to Arabic science were Christians and Jews who lived in an Islamic environment, at the peak of creativity – from the 12th to the 14th centuries – Muslims predominated. Nevertheless, all of these contributors were drawn from a variety of ethnic backgrounds representative of the peoples living within a vast region, stretching from present-day Morocco to Afghanistan, including Spain. This has led many to call this science either "Islamic" or "Arabic-Islamic" science.

Even today, however, there are no general histories of this tradition in astronomy, mathematics, optics, and medicine, which was the most advanced in the world from the 8th to the 14th centuries. Consequently, to attain an overall view of the nature, extent, and significance of the advances made by Arabic science, the reader must consult a variety of sources. This applies even more to such fields as alchemy, geography, and pharmacology.

The foundations of Arabic science laid by the classical Greek tradition have been sketched by ROSENTHAL, who provides vignettes, commentaries and selections from translations, adaptations, and further elaboration of Hellenic thought in such fields as philosophy, logic, medicine, geography, astronomy, musicology, the occult sciences, and literature. The work contains classifications of the sciences as understood by the Arabs, including the division between the Islamic or religious sciences, and those that the Arabs called the ancient or foreign Greek sciences. This account ought to be supplemented by SABRA (1988), which provides a more up-to-date survey of the early translators and commentators, along with a sketch of the evolving institutional structures. It offers concise assessments of significant achievements in Arabic astronomy, mathematics, optics, engineering, and timekeeping, which reflect current understandings in the history of those fields.

Although NASR is useful for its attempt to locate Arabic-Islamic science within a cultural and religious context, it is an idiosyncratic and somewhat dated view. The thrust of Arabic science is presented as one devoted to mystical unity, to gnosis, and Nasr argues that Arabic science deliberately took the path of the mystical unity of all knowledge, rather than the analytic one leading to modern science as we understand it. This is a position at odds with the view of leading contemporary historians of Arabic science, who have found that there were many innovations in its core disciplines that lead directly to modern science. Used with caution, Nasr's account contains helpful portraits of intellectual figures in the history of Arabic science along with important insights. It also offers translations from various Islamic authors. However, its accounts of major scientific figures need to be updated by reference to the *Dictionary of Scientific Biography*.

HUFF offers a broader, more current, and developmental view of the trajectory of Arabic science. It locates Arabic science within its religious, legal and institutional settings, and explores the relationship between law, the *madrasas* (Islamic colleges) and the pursuit of the natural sciences. Though focusing on developments in astronomy, it provides brief non-technical summaries of major scientific developments, as well as details of significant advances in medicine and medical education. As a sociological inquiry, it places more stress on the social and cultural context of Arabic science than on technical exposition. Its bibliography covers much of the technical literature in astronomy, mathematics, optics and medicine, as well as the specialized literature on Islamic law, philosophy and theology. Its comparative approach aids the understanding of contrasting patterns of development of science and society in Islam, China, and the European West during the golden era of Arabic-Islamic civilization.

Considerable progress in the understanding of the exact sciences in Arabic-Islamic civilization has been made since the early 1970s. BERGGREN's 1986 study is a good introduction to basic mathematical concepts and their development, including Islamic arithmetic, decimal fractions, square roots, algebra, geometry and trigonometry. BERGGREN's 1985 article gives a concise overview of these developments, but without historical and biographical sketches.

Of all the sciences pursued by the Arabs, astronomy has been the most extensively studied of late, though on the basis of only a small fraction of the scientific manuscripts known to exist. This has resulted in the discovery of Arabic treatises containing innovative reforms of the Ptolemaic models and the tantalizing suggestion that these reforms influenced Copernicus. The many Arab (and Persian) astronomers working in this astronomical tradition have been dubbed the Marāgha school because of their affiliation with the observatory built in Marāgha south-west of Tabriz in Iran c.1257–59, under the direction of Nasir al-Din al-Tusi (d.1274). SAYILI provides a pioneering general history of the development of the observatory in Islam, including Marāgha. It also contains an appendix devoted to the reasons for the decline of Arabic science.

The early results of the discovery (in the late 1950s) of the theoretical advances of the Marāgha astronomers are collected in KENNEDY *et al.* There the rolling device of two nested circles used to represent motion in a straight line, the "Tusi-couple", named after the astronomer al-Tusi, is identified, and suggestions are made that knowledge of this method was transmitted to Copernicus through channels yet to be verified. SALIBA represents the results of a second generation of historians of Arabic science studying these materials, and greatly amplifies the range of individuals associated with the Marāgha school and their accomplishments. Chapter 14 of this work is the most recent overview of these discoveries, their significance, and suggestions for future research.

The two books by KING (1986 and 1993) reveal the extreme sophistication of Islamic timekeeping and its relationship to mathematical astronomy from the early years of Islam to the 14th century. Although most of the papers are technical in nature, much can be learned from them by the general reader. These studies are the most extensive on the *zij* tables – that is, lists of planetary observations recorded systematically as ephemerides by location, along with advice for their use. Some of these tables contain over 250,000 entries and were meant to provide the basis for universal timekeeping.

King has pointed out the existence of both a folk (religiously guided) tradition of timekeeping and a more advanced tradition based on knowledge of mathematics and Ptolemaic astronomy throughout the history of Islam. It is the existence of these two separate traditions that accounts for the fact that many ancient buildings in the Middle East, including many mosques, are not perfectly aligned with Mecca – the direction

called the *qibla* – even though the knowledge of such alignment was readily available. Chapter 3 of King's *Islamic Mathematical Astronomy* contains a valuable overview of the flourishing school of Mamluk astronomy of the 14th and early 15th centuries. In addition, King's work on the *muwaqqit*, the official timekeeper in the mosque, briefly reported in that chapter, represents an important yet still only vaguely understood aspect of Arabic science and its place in Islamic civilization.

Another field in which the Arabs excelled and contributed to universal science was optics. In many ways optics in the medieval period played a role similar to physics in the 20th century, bringing together observation, mathematics, theory and experiment. SABRA (1987) "Optics, Islamic", is a penetrating account of the development of optics from the Greeks (Euclid and Ptolemy), through the early Arab students of optics, the pioneering work of Ibn al-Haytham (d. c.1040), to Kamāl al-Din al Fāris (d. c.1320) and his European counterpart, Theodoric of Freiberg (d. c.1310). LINDBERG (1976) remains a useful study of the development of optics, but needs to be read in conjunction with more recent studies, such as the introduction to SABRA (1989), a translation of the first three books of Ibn al-Haytham's treatise on optics (*Kitāb al-Manāzir*). Sabra's discussion brings out the many innovative aspects of Ibn al-Haythams's work, noting especially the "modern" flavor of his procedures, and his commitment to the methods of observation and experiment. Sabra points to the direct link between Kamāl al-Din's successful explanation of the rainbow and his study of and commentary on al-Haytham's earlier treatise. Sabra highlights in addition the fact that Kamāl al-Din employed innovative experimental procedures.

There are other fields to which Arab scientists contributed, especially in medicine, but these are largely reported in specialized journals. Some are discussed in the 2nd edition of the *Encyclopedia of Islam*, though the reader must first determine the Arabic term for the subject. The best source for the lives and work of many significant Arab scientists is the *Dictionary of Scientific Biography*.

The problem that continues to fascinate all students of history, especially contemporary Muslims of the Middle East, is the question of exactly when and why Arabic science came to an untimely end, instead of giving birth to modern science? The more historians have studied and identified the scientific innovations of Arabic science – especially in astronomy, mathematics, and optics – the more pressing the question has become. For the profundity of those innovations suggests that Arabic science in various specialized areas was making considerable progress toward modern science, and, prior to the 14th century, was far more advanced than the West. Its subsequent decline is clearly a case of waning creativity. To grapple with this problem, SABRA (1987), "The Appropriation and Subsequent Naturalization of Greek Science in Medieval Islam", offers an overview of the development of Arabic science. It consists of a three-phase assimilation and maturation pattern followed by a fourth stage of decline. In this latter stage, according to Sabra, theoretical inquiry was placed in the service of religion, thereby deflecting the pursuit of theoretical innovation. King reiterates this theme in the first chapter of *Astronomy in the Service of Islam*.

Building on Sabra's insights, Huff maintains that the pursuit of the natural sciences in Islam was never fully institutionalized, since they were not incorporated into the curricula of the Islamic colleges (*madrasas*). In addition, he points to the great differences in legal conceptions between Islam and the West, and the fact that the West, through its legal revolution of the 12th and 13th centuries, created many spheres of legal autonomy for corporate bodies – cities and towns, guilds, and universities – which were absent in Islamic law. Consequently, the process of transmitting this Greek and Arabic scientific tradition to the West in the 12th and 13th centuries takes on considerable significance. D'ALVERNY and LINDBERG (1978) both provide overviews of this process. Once the Europeans had acquired this Greek and Arabic knowledge and placed it at the center of study in the universities, a platform of disinterested inquiry, largely free from political and religious censors, was created. This institutional structure, according to Huff, supported the continuous study of science, building freely on the advances of the Arabic-Islamic world that lacked such institutional arrangements. Huff also points out the underlying difference in conceptions of the rationality of man and nature that were built into the contrasting legal and theological structures of Islam and the West.

SAUNDERS is a thought-provoking essay on the general subject of decline in Islamic civilization. It covers a wide range of views of earlier writers, including matters of political stability and tolerance, racial mixing, competing linguistic communities, economic factors, foreign invasions, theological intolerance, and geographic dispersion.

TOBY E. HUFF

Archaeology

Bibby, Geoffrey, *The Testimony of the Spade*, New York: Knopf, 1956; London: Collins, 1957

Ceram, C.W. [Kurt Marek], *Gods, Graves, and Scholars: The Story of Archaeology*, translated from the German by E.B. Garside, New York: Knopf, 1951 (original edition, 1949)

Daniel, Glyn, *A Hundred and Fifty Years of Archaeology*, 2nd edition, London: Duckworth, 1975; Cambridge, Massachusetts: Harvard University Press, 1976

Daniel, Glyn (ed.), *Towards a History of Archaeology*, London and New York: Thames and Hudson, 1981

Stiebing Jr, William H., *Uncovering the Past: A History of Archaeology*, Buffalo, New York: Prometheus Books, 1993

Trigger, Bruce G., *A History of Archaeological Thought*, Cambridge and New York: Cambridge University Press, 1989

Willey, Gordon R. and Jeremy A. Sabloff, *A History of American Archaeology*, 2nd edition, San Francisco: W.H. Freeman, and London: Thames and Hudson, 1974; 2nd edition, San Francisco: W.H. Freeman, 1982

Winstone, H.V.F., *Uncovering the Ancient World*, London: Constable, 1985; New York: Facts on File, 1986

The popular image of archaeology owes more to romance than to realism. Images of gold-laden tombs and lost cities in the jungle abound, and the moment of discovery overshadows the

long process of excavation, measurement, and laboratory analysis that inevitably follows. Popular histories of archaeology have traditionally reflected, and bolstered, the discovery-oriented image of the science. Since the mid-1970s, however, a series of new works has brought greater breadth and depth to the history of archaeology.

The classic work of the "great discoveries" school is *Gods, Graves, and Scholars*, published by the German archaeologist Kurt Marek under the pseudonym C.W. CERAM. Written with the stated intent of revealing the human drama behind dry excavation reports, it offers a parade of spectacular discoveries and colorful excavators. Beginning with the early civilizations of the Aegean – Crete, Mycenae, and Troy – it moves on to Egypt, Mesopotamia, and finally to Central America. The stories are exciting, and Ceram tells them well enough to send readers hunting for more detailed treatments. The whole, however, is somewhat less than the sum of its parts. The sheer diversity of Ceram's chosen subjects undercuts any sense that they form part of a single, larger story.

STIEBING's brisk survey tells many of the same stories that appear in Ceram. It places them, however, within a narrative substantially more integrated and wide-ranging. Sacrificing detail for geographic scope, Stiebing reviews pioneering excavations not only in the Mediterranean, Middle East, and Central America, but also in areas – such as East Asia, sub-Saharan Africa, and North America – that have traditionally received little attention from historians of archaeology. The survey extends, in principle, from the Renaissance to the present day, but the years before 1860 and after 1925 are covered only in a quickly-sketched overview. *Uncovering the Past* is, consequently, less a comprehensive history of archaeology than a study of what Stiebing describes as the discipline's coming of age.

Histories of archaeology, particularly general surveys, often focus on sites and artifacts while neglecting the ideas that guide their interpretation. TRIGGER redresses the balance in his densely packed, intensely analytical work – the outgrowth of a university course entitled "The History of Archaeological Theory". Ideas, and systems of ideas, take center stage throughout the book. Well-versed in the historiography of science, Trigger links the work of Soviet, European, and North American archaeologists not only to the work of their predecessors and contemporaries, but also to their cultural milieus. Trigger's discussion of the 20th century, which occupies more than half the text, achieves a level of analytical rigor and fine-textured detail unmatched elsewhere. Indeed, the book's sheer intellectual density is its principal drawback: the sections dealing with the later 20th century may be hard going for readers without some background in archaeology or its history. The book concludes with a comprehensive bibliography and an interpretative essay – invaluable tools for further research.

The surveys by Stiebing and by Trigger, read in conjunction, offer an excellent overview of the history of archaeology. They are not perfect complements, however, and can be usefully supplemented by the works below, which deal in greater depth with slightly narrower subjects.

DANIEL (1975), a modestly revised reprint of his earlier *One Hundred Years of Archaeology* (1950), focuses on the breakthroughs made – in Europe and the Middle East – by 19th-century Europeans. It treats the European pioneers in greater detail than Stiebing and with more assurance than Trigger. Although it has dated badly in some areas – particularly in its discussions of 19th-century geology and the impact of Darwinian evolution – its narrative core remains intact, and its treatments of archaeological field methods and the development of prehistoric chronologies remain unsurpassed. DANIEL's 1981 book consists of short papers that build on *150 Years of Archaeology* by treating specific aspects of the early (pre-1925) history of archaeology. The papers, though uneven in quality and approach, offer useful insights into archaeological thought in neglected areas such as Eastern Europe, Iberia, Belgium, and the British Commonwealth. As a group, they illuminate the connections between archaeological ideas and their cultural context.

Histories of the archaeological exploration and interpretation of particular regions abound. Trigger's bibliographic essay provides a useful guide, but three, in particular, are worthy of specific mention. WINSTONE offers a well-rounded treatment of archaeological work on the literate civilizations of the Aegean and Middle East that highlights the complementary roles played by artifacts and texts. Winstone treats the major civilizations in discrete chapters, but intersperses the chapters so that the work as a whole unfolds chronologically. The reader can thus choose to read the chapters about Mesopotamia, for example, as a group or within the context of the larger narrative. BIBBY, as the title of his work suggests, deals with preliterate societies known only through their artifacts. Intended both as a history of archaeology and as an introduction to European prehistory, Bibby uses graceful prose and numerous illustrations to show how archaeologists have used artifacts to reconstruct the cultures that produced them. His focus on artifacts and their interpretation makes his work a useful supplement to Daniel (1975), which deals with many of the same sites, but places the interpretations within a broader theoretical context.

WILLEY & SABLOFF survey the history of archaeological research in the New World. They give some attention to key investigators and significant sites – providing extensive illustrations of both – but their principal concern, like Trigger's, is with ideas. The core of their work examines archaeologists's attempts, between 1840 and 1960, to classify the varied cultures of the Americas and to reconstruct their chronological relationships. They follow the American convention of treating archaeology as a branch of anthropology, rather than as an essentially autonomous discipline. Unfortunately, their survey offers only brief comments on the post-1960 era, when proponents of the "New Archaeology" reasserted the centrality of anthropological ideas within archaeology.

A. BOWDOIN VAN RIPER

See also Prehistory: archaeology and anthropology

Archimedes c.287–c.212 BC

Greek mathematician

Clagett, Marshall (ed.), *Archimedes in the Middle Ages*, 5 vols, Madison: University of Wisconsin Press, 1964–84

Dijksterhuis, Eduard Jan, *Archimedes*, translated from the Dutch by C. Dikshoorn, Copenhagen: Munksgaard, 1956; revised edition, with a new bibliographical essay by Wilbur Knorr, Princeton, New Jersey: Princeton University Press, 1987 (original edition, 1938)

Dollo, Corrado (ed.), *Archimede: Mito tradizione scienza*, Florence: Olschki, 1992

Favaro, Antonio, *Archimede*, Genoa: Formiggini, 1912

Heiberg, J.L., *Quaestiones Archimedeae*, Leipzig: Klein, 1879

Heiberg, J.L. (ed.), *Archimedes Opera Omnia, cum Commentariis Eutocii*, 3 vols, Leipzig: Tübner, 1880–81; reprinted, Stuttgart, Tübner, 1972–75

Knorr, Wilbur, "Archimedes and the *Elements*: Proposal for a Revised Chronological Ordering of the Archimedean Corpus", *Archive for History of Exact Sciences*, 19 (1978): 211–90

Laird, W.R., "Archimedes among the Humanists", *Isis*, 82 (1991): 629–38

Schneider, Ivo, *Archimedes: Ingenieur, Naturwissenschaftler und Mathematiker*, Darmstadt: Wissenschaftliche Buchgesellschaft, 1979

The importance of Archimedes lies both in his work (geometry, hydrostatics, statics, arithmetic) and in the scientific ideal he has embodied up to the present day. His name is linked to some geometrical discoveries, such as the formula for the volume of a sphere or that for the area of a circle, to his sophisticated demonstrative procedures, and to his combination of geometry and physics in order to study centres of gravity. Moreover, Archimedes is reported by several historians (Polybius, Livy, Plutarch) as having defended his city against the Romans by means of extraordinary war machines. The circumstances of his death (killed by soldiers when Syracuse was taken) and the fame of his inventions generated an anecdotal tradition, in which Archimedes gradually became the epitome of the man of genius, forced by the necessities of real life reluctantly to turn from his speculative pursuits to the practical applications of mathematics.

The scholarship on Archimedes has generally focused on his "scientific" production, comparing it to previous works, analyzing its demonstrative procedures or tracing links between the various texts of the corpus. Other issues include concern over the reliability of some of the reports on Archimedes' life, his lost works, and whether Plutarch's famous portrait, according to which Archimedes recoiled from the practical aspects of mathematics, is a "true" description. HEIBERG's (still standard) edition of Archimedes' *Opera Omnia*, (1880–81), was preceded by his doctoral dissertation (1879). The dissertation is a very good source of information on the extant manuscripts and their filiations, on language and terminology, and on testimonies regarding Archimedes and others he mentions in his work. Heiberg also put a number of new points on the agenda: the problem of the heuristic process behind Archimedes' finished and incredibly concise proofs, hypotheses on the nature of the lost works, and the problem of the chronology of the extant books. Although a definite answer to the question of dating is not given, the order in which Heiberg discusses the books was generally adopted as the standard chronological order, and remained unchallenged until Knorr's article.

One of four articles on Archimedes by Wilbur KNORR published in 1978, "Archimedes and the Elements" has given a new turn to studies on the subject. While reconsidering the chronology, he aims to reinsert Archimedes within the context of his times, when the circulation, production, and reproduction of texts were such that it is likely that most of them went through more than one edition or version (not necessarily at Archimedes' hands). Knorr postulates the existence of lost first editions of works such as "Spirals", whose traces survive in authors such as Hero and Pappus. Supported by linguistic usage and by Archimedes' own introductions to his works, Knorr establishes the dating of the texts on the basis of their lesser or greater similarity to Euclidean terminology and procedures – on the assumption that Archimedes would have been closer to Euclidean geometry in his early days, developing characteristic traits later on.

A more general survey is given in FAVARO's booklet, which focuses on the historical testimonies of Archimedes' life and achievements. Very comprehensively researched, it still is a standard work for a critical analysis of such sources as Silius Italicus or Diodorus. It is also the quickest method to discover which classical authors mention Archimedes.

DIJKSTERHUIS combines general background and mathematical results – it solves the problem of making the latter accessible to the modern reader by translating the propositions literally and paraphrasing the proofs. Dijksterhuis also brings up the problem of Archimedes' attitude to "practical" mathematics in relation to the interpretation of Archimedes' "Letter to Eratosthenes on the Method", in which geometrical results are attained via a combination of formulas on the centres of gravity and the division of areas into infinite lines. Archimedes himself says that his method is not to be considered rigorously demonstrative: yet, is it because of mechanics, or because of the use of infinitesimals? Dijksterhuis favours the latter hypothesis, within the wider framework of an interpretation that sees no stigma attached to mechanics in Archimedes' actual practice.

Another good survey is by SCHNEIDER – valuable for his vast knowledge of the literature on the subject, including histories of technology. Schneider aims to show how the different professional guises of Archimedes (engineer, mathematician, "scientist") hang together, and finds a sort of ideal unity between practice and theory in his astronomy and his building of astronomical instruments.

The remaining three works on the list deal with Archimedes' fortune in later times. The volume edited by DOLLO gathers various papers, both on Archimedes in his own time (e.g. Cambiano explores the relation between various heuristic stages in his work) and from late antiquity onwards (Rashed on Arabic reception, Baldini on Archimedes in the 16th century, Micheli on the 19th and 20th centuries). The book as a whole charts the significance of Archimedes not only as a source, but as a role-model for later generations of scientists.

CLAGETT's monumental publication is an incredibly rich collection of texts ranging from the 12th to the 16th centuries, which includes reworkings, commentaries, paraphrases of Archimedes' works, and some information on the anecdotal tradition linked to him. It is also an impressive testimony to the many different directions that could be followed starting from Archimedes' work, and to the vivacity of medieval "science".

Finally, LAIRD's all too short article fills an important gap – namely, the significance of Archimedes for Italian "humanist" mathematicians (Commandino, Tartaglia, Cardano, del Monte, Maurolico) and therefore for the 16th-century revival of Greek science. The author argues that Archimedes' pre-eminence (it was commonplace to mention him as the "prince of geometers") was increased by the interest in his historical persona, in its turn rekindled by the renewed success of authors such as Polybius and Plutarch. Laird adds another important chapter to the story of how Archimedes has been seen not only as a "scientist", but as the paragon of science, in its dialectic between the pure and the applied.

SERAFINA CUOMO

Aristotle 384–322 BC

Greek philosopher

Balme, D.M., L. Minio-Paluello, G.E.L. Owen and L.G. Wilson, entry in *Dictionary of Scientific Biography*, edited by Charles Coulston Gillispie, vol. 1, New York: Scribner, 1970

Boylan, Michael, *Method and Practice in Aristotle's Biology*, Washington, DC: University Press of America, 1983

Cole, F.J., *A History of Comparative Anatomy: From Aristotle to the Eighteenth Century*, London: Macmillan, 1944; reprinted, New York: Dover, 1975

Lang, Helen S., *Aristotle's Physics and Its Medieval Varieties*, Albany: State University of New York Press, 1992

Lloyd, G.E.R., *Early Greek Science: Thales to Aristotle*, London: Chatto and Windus, and New York: Norton, 1970

Lloyd, G.E.R., *Greek Science after Aristotle*, London: Chatto and Windus, and York: Norton, 1973

Randall, John H., *Aristotle*, New York: Columbia University Press, 1960

Solmsen, Friedrich, *Aristotle's System of the Physical World: A Comparison with His Predecessors*, Ithaca, New York: Cornell University Press, 1960

Aristotle's mark on Western thought has been comprehensive and enduring. In the sciences alone his influence continued to be felt in the fields of physics, cosmology, and biology well into the 17th century. As a result, the literature on Aristotle is rich in accounts of both his influences and his antecedents.

LLOYD (1970) traces early Greek speculations in astronomy, physics, biology, and mathematics in relation to the evolution of a scientific method. These histories of the ancient sciences culminate in Lloyd's penultimate chapter on Aristotle, in which his theories are compared with those of his predecessors. Lloyd sees Aristotle's qualitative approach to physics and biology as a step backwards from the atomists' earlier attempts at quantitative methods, and considers Aristotle's cosmology a clumsy response to earlier attempts to reduce irregular planetary motion to regular courses. However, Lloyd does see embodied within Aristotle's works three achievements in ancient science: first, the accumulation of much descriptive knowledge in the fields of biology and astronomy; second, the formulation of scientific problems such as the nature of change; and third, the development of methodological principles.

SOLMSEN's dense philosophical treatise attempts to link Aristotle with the pre-Socratics. In particular, he claims that Aristotle's debt is three-fold: that Aristotle inherited the subjects he addresses in his physical treatises from the pre-Socratics; that he takes up questions that are not arbitrary; and that his answers are not wholly original. Solmsen's route from Aristotle to the pre-Socratics is through Plato, specifically his later philosophy on genesis in the *Timaeus*, and on movement in the *Cratylus*, the *Sophist*, and the *Theaetetus*. Solmsen notes the Platonic components in Aristotle's system – his methodology, logical distinctions, and view of the nature of the cosmos – but he adds that the arguments in Aristotle's physics grew out of Plato's reactions to the pre-Socratics, in particular, to Parmenides and Zeno.

RANDALL claims that there is a clear disparity between Aristotle's scientific principles and his scientific practice. He acknowledges the explicit Platonism in Aristotle's notion of science: a formalism modeled on geometry, where structure is separated from experience. At the same time Randall notes Aristotle's indomitable empiricist proclivities, which became the basis of his functionalism. Randall's main theme is this tension between Aristotle the *logikos* and Aristotle the *physikos*, as it is lived out in his attempts to reintegrate Platonic structure into the experience of the world. Moreover, Randall follows this tension from Aristotle into later Greek and medieval Aristotelianism, and all the way up to modern times.

BOYLAN traces the development and practice of Aristotle's biology in order to rebut the claim that his actual biological investigations were inconsistent with his methodological principles. Boylan first lays out the context within which Aristotle's biology emerged, one that has its roots in Parmenides' distinction between *nous* and *aisthesia*. By Aristotle's time, these two concepts had become the basis of rationalism and empiricism, both of which Aristotle required in order to formulate valid explanations. Boylan examines in detail Aristotle's modes of biological explanation and then presents samples of his biological practice in order to show consistency between the two. Boylan concludes by describing the consequences of Aristotle's biology and its relevance to modern biology.

LLOYD (1973) shows how enduring were Aristotle's scientific doctrines, particularly in the fields of physics, mathematics, astronomy, and biology, from the times of his immediate successors at the Lyceum to the late Hellenistic and the Roman imperial eras. Lloyd draws a clear distinction between modern and ancient science, noting that the modern sense of science as a means to material progress never caught on in ancient times, despite the occasional interest and patronage shown by some monarchs in the possible technological by-products that could be used in warfare. Lloyd's conclusion is that no new rationale for scientific inquiry arises after Aristotle, and that the continuity of Aristotelian thought during these times

is punctuated only by occasional variations in theory and practice.

LANG focuses on the medieval commentators of Aristotle's *Physics*. In maintaining a distinction between the *Physics* and Aristotelian physics, she shows how Aristotle's commentators radically reworked his arguments in order to redefine problems and offer their own solutions. She begins by establishing the unity among the rhetoric, logic, and context of the arguments in the *Physics* itself, and then systematically analyzes the way in which five commentators have reinterpreted his work. Lang first examines Philonus, who fashioned his own notion of nature as an intrinsic mover, a ploy that Lang sees as part of his program to reconcile Plato and Aristotle. Next she looks at Albertus Magnus: one of the first Latin commentators to rediscover Aristotle, he was a Neoplatonic thinker who interpreted the arguments in the *Physics* as a hierarchical treatment of forms of being. Lang moves on to describe how Aquinas altered the rhetorical and logical structures of the *Physics* when he divided the work up for classroom lectures; in so doing, Aquinas turns Aristotle's thesis of eternal motion into a proof of the existence of God. Lang then shows how Buridan supplemented and corrected Aquinas, although he agreed that the *Physics* is a proof of the existence of God. Finally, she examines the commentary of John Duns Scotus, who appropriated Aristotle's definition of place in the *Physics* to argue for the existence of angels.

COLE takes Aristotle's honorary title – "founder of biological science" – seriously, for, although he ostensibly traces the history of anatomy from Aristotle through Galen, Vesalius, Leonardo, and Harvey among others, Aristotle remains the norm by which his successors are gauged, as either progressive or retrograde. Cole points out many instances in which Aristotle's anatomies were often contradicted by later observers only to be vindicated by subsequent observers, as was the case, for example, with the description of cetacea as mammals and of sponges as animals. In addition, Cole seems to delight in pointing out the primacy of Aristotle's discovery whenever his successors claimed some new anatomical entity, calling them "the first after Aristotle to discover". Though his admiration for Aristotle is unabashed, Cole does not shrink from criticizing him for accepting without verification the reports of fishermen and hunters, and for denying on occasion the testimony of his own senses in favor of the logic of argument.

A concise but comprehensive account of Aristotle's science is the article by BALME *et al.* in the *Dictionary of Scientific Biography*. The author's rely heavily on the manuscript tradition to follow Aristotle's development in three areas: natural history and zoology; anatomy and physiology; and method, physics, and cosmology. In the subsection, "Natural History and Zoology", Balme notes how Aristotle's original plan for classifying animals evolved as he added more data from his ongoing observations. Sometimes, though, when empirical data were lacking, he changed his classification via *a priori* arguments and examples that were functionally, not morphologically, analogous. Wilson, in the subsection "Anatomy and Physiology", calls Aristotle the "founder of detailed anatomical study" for his careful observations of cardiovascular systems, offering in the process an explanation for Aristotle's miscounting of the number of cavities in the heart. Owen, in the subsection "Method, Physics, and Cosmology", traces Aristotle's development of science in his early works, *Posterior Analytics*, *Topics*, *Physics*, *De caelo*, and *De generatione*, to find Plato's heavy imprint but no evidence yet of empiricism. In the last subsection, "Tradition and Influence", Minio-Paluello, by following Aristotle through Greek, Latin, and Islamic manuscripts, argues for two enduring aspects of his science: the methodological and the conceptual-linguistic.

LAWRENCE SOUDER

See also Greece: general works; Religion and Science: Medieval

Arithmetic

Ascher, Marcia and Robert Ascher, *Code of the Quipu: A Study in Media, Mathematics, and Culture*, Ann Arbor: University of Michigan Press, 1981

Cajori, Florian, *A History of the Logarithmic Slide Rule and Allied Instruments*, New York: Engineering News, and London: Constable, 1909

Cajori, Florian, *A History of Mathematical Notations*, vol. 1, Chicago: Open Court, 1928

De Morgan, Augustus, *Arithmetical Books from the Invention of Printing to the Present Time*, London: Taylor and Walton, 1847

Gillings, Richard J., *Mathematics in the Time of the Pharaohs*, Cambridge, Massachusetts: MIT Press, 1972

Hill, G.F., *The Development of Arabic Numerals in Europe, Exhibited in Sixty-Four Tables*, Oxford: Clarendon Press, 1915

Ifrah, Georges, *From One to Zero: A Universal History of Numbers*, translated from the French by Lowell Bair, New York: Viking, 1985 (original edition, 1981)

Knott, Cargill Gilston (ed.), *Napier Tercentenary Memorial Volume*, London and New York: Longmans Green, 1915

Menninger, Karl, *Number Words and Number Symbols: A Cultural History of Numbers*, translated by Paul Broneer, Cambridge, Massachusetts: MIT Press, 1969

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Schimmel, Annemarie, *The Mystery of Numbers*, New York: Oxford University Press, 1993

Seidenberg, A., "The Ritual Origin of Counting", *Archive for History of Exact Sciences*, 1 (1962): 1–40

Smith, David Eugene, *Rara Arithmetica: A Catalog of the Arithmetics Written Before the Year MDCI*, 2 vols, Boston and London: Ginn, 1908; 4th edition, New York: Chelsea, 1970

Yeldham, Florence A., *The Teaching of Arithmetic Through Four Hundred Years, 1535–1935*, London: Harrap, 1936

Zaslavsky, Claudia, *Africa Counts: Number and Pattern in African Culture*, Boston: Prindle Weber and Schmidt, 1973

History teaches us that the term arithmetic has carried much broader and multifaceted meanings than today's connotation. To the ancient Greeks who followed Pythagoras, *arithmetica* comprised the study of the theoretical properties of integers and rational numbers. (On the other hand, practical dealings with numbers in the classical Hellenic world was called *logistica*.)

In Europe, up to the Renaissance, mathematics was divided into what came to be known as the quadrivium: arithmetic, geometry, astronomy, and music. Only since the early decades of the 17th century has arithmetic slowly taken the shape we recognize today.

Some form of arithmetic is common to every civilization, and, as such, arithmetic precedes classical Greece by millennia. Menninger and Ifrah are two works that provide very broad coverage of the range of the history of arithmetic. The development of connections between counting numbers and the languages of many civilizations comprises almost half of MENNINGER, the Indo-European languages receiving the most extensive treatment. From number words, Menninger progresses to an account of pre-literate number systems, fingers, sticks, and knots. In Ifrah, this same material is covered with less general linguistic analysis. Both books contain several tables summarizing and comparing the terminologies that different peoples used for numbers, and both books are illustrated, Ifrah generously so.

The number sequence was not created or "made"; it grew and evolved slowly and randomly, along with man and his various languages. According to the conventional wisdom, the practical needs of the first societies of pre-literate humanity led to the development of counting, numerology, and arithmetic. On the other hand, SEIDENBERG argues forcefully that numbers did not exist prior to their ritual application, and that counting originated to mimic a portion of the Creation ritual. Connections between numbers and spiritual concerns have persisted throughout history. SCHIMMEL's book provides mystical and religious stories about each integer, from 1 to 40, as well as a few more, world-wide, and from cultures ancient to modern.

The arithmetic of the Incas of South America is presented with helpful photographs and many carefully labelled diagrams of quipus in ASCHER & ASCHER. The quipu was a system of knots tied in colored strings, which recorded numbers and on which have been found some arithmetic calculations, including multiplications and proportions. Arithmetic in sub-Saharan Africa is discussed in general terms in the first part of ZASLAVSKY. The last two chapters focus on the number systems of the Yoruba and Edo of Nigeria and several peoples of East Africa. Zaslavsky ranges from counting, games and number mysticism, the designation of numbers with fingers, sticks, bones, and strings, to practical matters of money, weights and measures.

The arithmetic of ancient Egypt, according to GILLINGS, was based on the two-times table and the ability to find two-thirds of any integer or rational number. Gillings discusses numerals in both hieroglyphics and hieratic script, analyzes many specific problems of pure and applied arithmetic taken from several papyri, and gives attention to the special role of fractions in ancient Egyptian arithmetic.

"An alphabet is . . . the highest stage in the development of writing", and the alphabets of many cultures have been employed to designate positive numbers. Beginning with a brief history of the alphabet, Menninger explains the Greek Attic and alphabetic numerals and Roman numerals, especially those of the Germanic states. The approach is more inclusive in Ifrah, in which many tables and diagrams support a generous account of the origins and development of Roman numerals. Ifrah also discusses Phoenician, Hebrew, Greek, Syriac, and Arabic alphabetic number systems.

Alphabetic and other repetitive numeral systems, no matter how popular in their respective cultures, were not well designed for computations. For this purpose, the abacus was widely used in Greek and in Roman times. Menninger's account traces the use of various forms of the abacus from classical societies, through Russian and oriental cultures, to the Middle Ages and the beginning of the Renaissance in Europe. PULLAN repeats this story and adds a good deal of information on the jettons (the counters) used on European counting boards and gives some ideas on how contemporary teachers can use the abacus in their classes.

"The ultimate stage of numerical notation" is place-value notation, which arose sometime during the second millennium BC. The Babylonian sexigesimal (base 60) system originated with the organized study of astronomy (its influence through trigonometry and the measurement of time can be detected today) and has been preserved on numerous clay tablets. Accounts of these numerals can be found in many sources: Ifrah, Menninger, and general histories of mathematics. Ifrah and Menninger also contain chapters on the (base 10) place-value systems of China and Japan. The (base 20) and other numeral systems of the Maya of Central America and their interlocking calendars are well illustrated in Ifrah. Over the past few years, much progress has been made in the translation and interpretation of Mayan glyphs.

The Hindu-Arabic number system used by most of the world today originated in India, exactly when and where is apparently lost, and was perfected by the Muslims. The progression of the symbols for the digits on which this system is based is illustrated in diagrams in Ifrah. HILL's collection gives a very rich sense of this progress in Europe, as the Hindu-Arabic numerals gradually displaced the Roman numerals in the late Middle Ages and the Renaissance. The history of zero is examined in Menninger. The largest collection of arithmetic books published from incunabula to 1600 is described in SMITH; this is an annotated bibliography with almost every title page reproduced and additional features of some books also illustrated. DE MORGAN reviewed books in the British Museum, and with only a few exceptions made rather terse comments (there are no illustrations).

There currently exists a clear boundary between the algebra of solving equations and arithmetic computations – especially the Rule of Three, the Rule of False Position, and many numerical puzzles. This demarcation was not recognized until a separate notation for algebra had been created. In tracing this evolution in much detail, CAJORI (1928) also presents many examples of the variations on the basic arithmetic algorithms.

The deficiencies of these algorithms for many computations, especially in astronomy, were met with the invention of logarithms. KNOTT gives a careful explanation of John Napier's first formulation of logarithms, some personal accounts of Napier's life and times, and an account of the improvements by Napier and Henry Briggs that led to our common logs. The slide rule, based on logarithms of lengths, was invented by William Oughtred in 1632 and developed the following year. "Slide rules have been adapted to almost every branch of the arts in which calculation is required" (at least until the advent

of electronic calculation in our own times), and their history is told in CAJORI (1909).

According to Robert Recorde (d. 1558), one of the earliest writers of mathematics textbooks in English, arithmetic "is marvellous, methinks, that such great matters may so easily be achieved by this Art". Using many examples and problems taken directly from English textbooks, YELDHAM traces the development of arithmetical pedagogy and teaching.

JOE ALBREE

Artificial Intelligence

Dreyfus, Hubert L., *What Computers Can't Do: The Limits of Artificial Intelligence*, New York: Harper and Row, 1972; revised edition, 1979

Fleck, James, "Development and Establishment in Artificial Intelligence", in *Scientific Establishments and Hierarchies*, edited by Norbert Elias, Herminio Martins and Richard Whitley, Dordrecht: Reidel, 1982

Ganascia, Jean-Gabriel, *L'Ame-machine: les enjeux de l'intelligence artificielle*, Paris: Seuil, 1990

Gardner, Howard, *The Mind's New Science: A History of the Cognitive Revolution*, New York: Basic Books, 1985

McCorduck, Pamela, *Machines Who Think: A Personal Inquiry into the History and Prospects of Artificial Intelligence*, San Francisco: W.H. Freeman, 1979

Searle, John, "Minds, Brains and Programs", *Behavioral and Brain Sciences*, 3 (1980): 417–57

Simon, Herbert A., *The Sciences of The Artificial*, Cambridge, Massachusetts: MIT Press, 1969; 3rd edition, 1996

Taube, Mortimer, *Computers and Common Sense: The Myth of Thinking Machines*, New York: Columbia University Press, 1961

Weizenbaum, Joseph, *Computer Power and Human Reason: From Judgment to Calculation*, San Francisco: W.H. Freeman, 1976

The expression "artificial intelligence" was coined by John McCarthy in 1956, officially declaring the birth of the field at a meeting held at Dartmouth College, New Hampshire. Pamela McCORDUCK, very much an enthusiast of the field, has written a detailed history in which she includes many interviews. She explains how this meeting gathered some 10 young mathematicians, psychologists, and electrical engineers who wanted to study the mind independently of its material manifestation in brains. Their project was based on the hypothesis that all the characteristics of intelligence could in principle be described precisely enough to permit their machine simulation. These young researchers all shared the belief that intelligence could be comprehended in a formal, scientific manner, and that the best instrument for the task was the digital computer. McCorduck describes this group of early researchers in artificial intelligence as a closed group, a "clan" whose nepotistic practices saw students pursuing the work of their pioneering mentors. McCarthy, Marvin Minsky, Herbert Simon, and Allen Newell made up the "hard core" of artificial intelligence. In 1957, McCarthy founded the first research center at the Massachusetts Institute of Technology (MIT), where work was oriented towards the construction of models and computer programs devoted to problem solving and theorem proving, chess playing, and pattern recognition. At the Carnegie Institute of Technology (later Carnegie-Mellon University), Newell and Simon formed another group and conceived the General Problem Solver, which presumed that the methods used to resolve problems were independent of their contents. The mathematician Seymour Papert joined Minsky and McCarthy at MIT to work on the development of intelligence in children and to finish the Logo Project, with the aim of "teaching children to think". Following the first General Problem Solver programs, another approach, devoted to the production of expert systems, was developed. Contrary to General Problem Solver, expert systems like Dendral and Mycin were based on the idea that specialized knowledge was essential to the efficient resolution of a problem.

FLECK proposes a sociological view of science, and shows that a focus on intelligent behavior provides the disciplinary context (psychology) of artificial intelligence, while its goals are various, due to the great variety of social interpretations and linguistic applications of the very term "intelligence". This aspect of artificial intelligence is typical of any specialty based on a technique that can be put to diverse uses; thus Fleck sees the problem of conflict and competition in the field of artificial intelligence as being directly tied to the focus on intelligence, a term lacking a precise social and cognitive denotation. Fleck explains how the emergence of the field of artificial intelligence was consolidated by its success in obtaining the financial support of the United States government's Department of Defense, principally under the Advanced Research Projects Administration (DARPA) and the Air Force. DARPA's decision to finance only a small number of research groups helped to concentrate resources, and thus computers, in three centers, headed by Minsky at MIT, Newell and Simon at CMU, and McCarthy, working since 1962 at Stanford.

TAUBE criticized artificial intelligence as early as 1961, and since the 1970s increasingly virulent attacks have been levied at the field. DREYFUS's history of the domain is very critical, attacking its philosophical prejudices and what he sees as the naiveté of its fundamental hypotheses. He acknowledges the strengths of its technical achievements, but exposes the distance between pretensions and results, and refuses to grant artificial intelligence the privileged status it seems to claim for itself. Dreyfus sees artificial intelligence as a continuation of the occidental tradition begun by Plato, for whom all knowledge had to be expressible in the form of explicit definitions. WEIZENBAUM, who had been one of the members of the artificial intelligence "clan" at MIT, rose up in 1976 against "the imperialism of instrumental reason which would impose a machine regime on humanity". He raised the issue of morality, reckoning that computers should not be allowed to influence certain aspects of life. The machine metaphor as a description of the mind's functioning appears dangerous to him, and he believes that instead of revolutionizing the world, the use of computers has helped to protect and consolidate American social and political institutions. Weizenbaum also explains that most artificial intelligence work arises more from technology than from science.

In the face of criticism, proponents of artificial intelligence have published a number of books, attempting to disqualify their opponents and develop an epistemological conceptualization of the "sciences of the artificial". For SIMON, one of

Astronomy: general works

Hoskin, Michael (ed.), *The General History of Astronomy*, 4 vols, Cambridge and New York: Cambridge University Press, 1984–95

Hoskin, Michael (ed.), *The Cambridge Illustrated History of Astronomy*, Cambridge and New York: Cambridge University Press, 1997

Lankford, John (ed.), *History of Astronomy: An Encyclopedia*, New York: Garland, 1997

North, John, *The Fontana History of Astronomy and Cosmology*, London: Fontana, 1994; as *The Norton History of Astronomy and Cosmology*, New York: Norton, 1994

Pannekoek, Anton, *A History of Astronomy*, New York: Interscience, and London: Allen and Unwin, 1961

Selin, Helaine (ed.), *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, Dordrecht: Kluwer, 1997

Thiel, Rudolf, *And There Was Light: The Discovery of the Universe*, translated from the German by Richard and Clara Winston, New York: Knopf, 1957 (original edition, 1956)

Wilson, Robert, *Astronomy Through the Ages: The Story of the Human Attempt to Understand the Universe*, Princeton, New Jersey: Princeton University Press, and London: Taylor and Francis, 1997

There are a great many general histories of astronomy, testifying to the field's attraction to the general public. The night sky, space science, and cosmology all prove fascinating to an audience beyond academia. This entry covers the best-known older text (Pannekoek) and the most scholarly general history of astronomy (Hoskin). It also covers four popular histories that have been published recently, all of which contain references to further literature, and one text that aims to synthesize the academic contributions to the history of astronomy.

PANNEKOEK, a leading astronomer of his time, covers the history of astronomy from antiquity to the mid-20th century in more than 500 pages. The section on ancient science concerns Babylonian, Egyptian, Chinese, Greek, and Arabic astronomy; the section on astronomy in the scientific revolution covers Copernicus, Brahe, Kepler, and Newton; the section on "astronomy surveying the universe" covers celestial mechanics, photography, spectrography and gives an intellectual history of cosmology and stellar physics. Pannekoek follows an established tradition with this kind of coverage. THIEL is a similarly structured earlier example. Whereas Thiel emphasizes the maturing of astronomy and heroic discoveries, Pannekoek puts special emphasis on the role of quantification and the intellectual craving for beauty. In both books, the history of technology is confined to the provision of tools.

HOSKIN's encyclopedia (1997) is a beautifully illustrated history from prehistory to the 1980s (to the Hertzsprung-Russell diagrams and the Hubble constant) in nearly 400 pages. Both theory and instrumentation are discussed and depicted but mostly in separate sections, and so the connection between the two is not always addressed. The institutional history of astronomy is largely ignored. There is an appended chronology and a useful section on further reading.

LANKFORD is in encyclopedic format with entries arranged alphabetically. It includes articles on individuals, subfields of astronomy, institutions, instruments, and countries. There is a bibliography at the end of each entry. The entries are generally well-written and a good proportion of the authors are astronomers.

The coverage of non-Western cultures in general histories of astronomy is generally limited to ancient cultures, such as Babylonia, ancient Egypt, and ancient China, as we have seen for Pannekoek and Thiel above. SELIN fills that gap in that it covers comprehensively astrology, astronomical instruments and astronomy of Africa, native North America, the Australian Aboriginal peoples, China, Egypt, the Hebrew peoples, India, Indo-Malay Archipelago, the Islamic World, Mesoamerica and Tibet. Arranged alphabetically in some 1,100 pages, the entries are sometimes short (especially the biographical and descriptive entries) and sometimes long and fundamental (such as the entry on "Rationality, Objectivity, and Method").

NORTH aims to synthesize detailed research in a survey that is nearly 700 pages long. As with all books in the Fontana/Norton series in the history of science, it is targeted at general readers and students. Organized largely chronologically, each chapter has a bibliographical essay attached to it. Approximately one third of the book is allocated respectively to antiquity, Europe from the medieval period to William Herschel, and the rise of astrophysics to space observatories and Stephen Hawking. This is the least successful of the Fontana/Norton books: it is a story of progress and the bibliographies are highly selective. The author argues that science consists of reducing the observed to a series of rules. In LANKFORD, utility is presented as less important for the historical development of the subject than human feeling for system and order.

WILSON is a history written by an astronomer for a non-scientific audience – it explains the science very simply and avowedly without the use of mathematics. Arranged in three sections according to instrumentation (the naked eye, the telescope, and instruments capable of detecting radiation beyond the optical spectrum), the book includes, however, little discussion of the instrumentation. Wilson conceives of astronomical instruments as simply extending human perception.

The most useful general history for professional historians of science is HOSKIN (1984–95). Editors and authors include well-known names in the history of astronomy: Olaf Pedersen, René Taton, Curtis Wilson, Owen Gingerich, and Michael Hoskin himself. In progress since 1984, this collection was conceived as a seven-volume work in four parts (some volumes are in progress). The articles do not carry footnotes but there is an extensive section of further reading at the end of each. Each volume covers theory, experimentation, observational methods, and (for the relevant periods) observatories. There are also chapters under such headings as "Sociology of astronomy", which, however, is primarily an institutional history.

ARNE HESSENBRUCH

See also Astronomy: non-European; Astrophysics

Astronomy: non-European

Aveni, Anthony F. (ed.), *Archaeoastronomy in the New World*, Cambridge and New York: Cambridge University Press, 1982

Aveni, Anthony F. (ed.), *World Archaeoastronomy: Selected Papers from the 2nd Oxford International Conference on Archaeoastronomy*, Cambridge and New York: Cambridge University Press, 1989

Cornell, James, *The First Stargazers: An Introduction to the Origins of Astronomy*, New York: Scribner, and London: Athlone Press, 1981

Cullen, Christopher, *Astronomy and Mathematics in Ancient China: The Zhou Bi Suan Jing*, Cambridge and New York: Cambridge University Press, 1996

Haynes, Raymond *et al.*, *Explorers of the Southern Sky: A History of Australian Astronomy*, Cambridge: Cambridge University Press, 1996

Ho, Peng Yoke, *Li, Qi, and Shu: An Introduction to Science and Civilization in China*, Hong Kong: Hong Kong University Press, 1985; Seattle: University of Washington Press, 1987

Hodson, F.R. (ed.), *The Place of Astronomy in the Ancient World: A Joint Symposium of the Royal Society and the British Academy*, London: Oxford University Press, 1974

Kaye, G.R., *Hindu Astronomy: Ancient Science of the Hindus*, Calcutta: Government of India Central Publications, 1924; reprinted, New Delhi: Cosmo, 1981

Kennedy, E.S., *Studies in the Islamic Exact Sciences*, Beirut: American University of Beirut, 1983

King, David A., *Islamic Mathematical Astronomy*, London: Variorum, 1986

Krupp, E.C., *Echoes of the Ancient Skies: The Astronomy of Lost Civilizations*, New York: Harper and Row, 1983

Nakayama, Shigeru, *A History of Japanese Astronomy*, Cambridge, Massachusetts: Harvard University Press, 1969

Ruggles, Clive L.N. and Nicholas J. Saunders (eds), *Astronomies and Cultures: Papers Derived from the Third Oxford International Symposium on Archaeoastronomy*, Niwot: University Press of Colorado, 1993

Selin, Helaine (ed.), *Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, Dordrecht: Kluwer, 1997

Sen, S.N. and K.S. Shukla (eds), *History of Astronomy in India*, New Delhi: Indian National Science Academy, 1985

Swarup, G.A.K. Bag and K.S. Shukla (eds), *History of Oriental Astronomy: Proceedings of an International Astronomical Union Colloquium no. 91*, Cambridge: Cambridge University Press, 1987

Walker, Christopher (ed.), *Astronomy Before the Telescope*, London: British Museum Press, and New York: St Martin's Press, 1996

The study of the sky is arguably the first science. The peoples of the old and new worlds used the movement of celestial objects to keep time, to guide them in hunting, navigating and planting, and to predict and explain terrestrial events. Our knowledge of the astronomical activities of these peoples comes from a variety of sources, including written materials from literate civilizations and surviving instruments and observatories. There is a vast literature on European sites such as Stonehenge, but scholarly work on the rest of the world is much more limited. This imbalance is slowly being rectified.

Books on the history of astronomy tended to start with the Greeks, with a passing mention of the Arabs as translators of Greek science. This has changed in recent years. In 1972 a joint symposium of the Royal Society and the British Academy was held on astronomy in the ancient world. HODSON's edited collection of essays is one of the first to give scholarly credence to astronomy in non-European cultures. Astronomical theories and practices are examined in several ancient cultures: Babylonian, Egyptian, Polynesian and Micronesian, Chinese and Maya. An interesting section contains papers comparing astronomical alignments in several cultures. Three other volumes from symposia are included here, all resulting from the Oxford international conferences on archaeoastronomy. AVENI's collection on world archaeoastronomy (1989) contains articles from a variety of disciplines, including astronomy, history, and art. It includes overviews of Chinese, Maya, and Southwestern United States' astronomy, and other studies arising from ancient artifacts, such as books, pictographs, and string constructions.

Papers from the third Oxford conference edited by RUGGLES & SAUNDERS range from the editors' overview of the study of cultural astronomy, in which they explain how different cultures perceive and interpret the sky according to their own worldview, to those discussing Chinese, Mesoamerican, Indian, and Islamic astronomical practices and beliefs.

CORNELL gives equal weight to the astronomical discoveries and practices of the Egyptians, Europeans, Native Americans (North, Central, and South), Africans, and Asians. This is one of the first studies to look at the astronomy of sub-Saharan Africa with a careful scholarly eye (despite calling Africa the "Dark Continent"). The book is very readable and accessible, is a good introduction to the subject with a useful bibliography. KRUPP has written a variety of articles and books, and has edited volumes, both scholarly and popular, on astronomy in non-European cultures. His 1983 book discusses science, myth, religion, architecture, timekeeping, city planning, and cosmology. Rather than arranging the chapters by culture, Krupp takes a topic such as calendars and discusses the similarities and differences in Kenya, Egypt, China, and Peru. This approach gives an excellent synthesis of astronomical practices around the ancient world. Although most of the articles in WALKER focus on Europe, the collection includes the latest scholarship on Egypt, India, the Islamic world, China, Korea and Japan, the Americas, Africa, and, uniquely, Australian Aboriginal, Polynesian, and Maori astronomy. The bibliographies are extensive, and the book includes some wonderful illustrations. It is clear that these kinds of studies are becoming more comprehensive and are produced more frequently, which is a reflection of the recent changes in curricula in higher education away from an entirely Eurocentric perspective. SELIN's encyclopedia is the first compendium to bring together scholarly articles with bibliographies on all the sciences in many different cultures. The astronomy section includes essays on Africa, the Americas, Australia, China, India, the Islamic world, and Tibet, to name a few. This is a

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Books and articles discussed in the entries are listed here under the name of the author/editor. The page numbers refer to the lists themselves, where full publication information is given.