

Historic Scientific Instruments and the Teaching of Science: A guide to resources.

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A guide to resources

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ABSTRACT: The development and use of scientific instruments has been an essential part of the growth of science in the past 400 years. Interest in historic scientific instruments has grown very considerably in the past two decades. Not only are the very early instruments preserved and studied. Increasing attention has been paid to instruments from the nineteenth and twentieth centuries. Collections of instruments have been gathered in museums and universities. Societies have been formed, conferences and meeting held. Catalogues, inventories, and historical studies have been published. Museum home pages are daily being added to the Internet. The following discussion is intended to provided a guide to the variety of sources teachers may find useful in

examining the role of instruments in relation to the History of Science and the Nature and Practice of Science components of the Syllabus.

INTRODUCTION

Historic scientific instruments provide a point of access for understanding the history of science. In recent decades there has been a growing interest in the preservation and documentation of scientific instruments. This to some extent parallels the expansion of academic history of science. With rapid change in the technology of science, instruments can rapidly become obsolete. Earlier this century most emphasis was given to preserving instruments from the eighteenth century and before. More attention has been paid in recent years to instruments from the nineteenth and twentieth centuries. With the exponential development of science in the last 200 years, numerous new types of instrument have been developed.

The term 'scientific instrument' is a convenient handle for describing a complex of technical artifacts used in various scientific and technical practices. It includes instruments used for explicitly scientific purposes such as laboratory galvanometers or astronomical spectrometers. There are also instruments and devices used for the demonstration of scientific principles in an educational context. Some of these have long antecedents in science teaching going back to the popular scientific lecturers of the eighteenth century or earlier. In some cases they represent simplified versions of precision instruments. A third category of scientific instrument represents instruments used in various technical practices such as navigation and surveying. The concept of 'scientific instrument' is discussed by Warner, 1990.

Instruments today described as 'scientific' were previously designated 'mathematical, optical and philosophical'. Up to about 1600 instruments were made of paper, wood or sometimes metal, especially brass. These were used for linear or angular measurement. They were the tools of mathematical practitioners such as land surveyors and were known as mathematical instruments. With the scientific revolution of the seventeenth century, new sorts of instruments were developed for investigating nature such as the barometer and the air pump. Those who investigated natural phenomena were known not as 'scientists' (a term only just coming into usage in English by the middle of the nineteenth century) but natural philosophers. The journal of the Royal Society of London, founded in 1660, was its *Philosophical Transactions*. So the instruments used to investigate natural phenomena were known as philosophical instruments. Around about 1600 the third category of

instruments - optical - also came into being. Lenses had been used for spectacles from the late medieval period. The combination of lenses to form a telescope seems to have been a Dutch invention of the 1590s. Galileo was quick to apply the new instrument to astronomy, observing sunspots and discovering four moons of Jupiter. The microscope was also developed in the seventeenth century. Robert Hooke's *Micrographia*, published in 1665, was based on demonstrations shown to the Royal Society of London.

The production of scientific instruments has of necessity undergone enormous changes over the last three or four hundred years, from a craft skill to large-scale industrial manufacture. Remarkable threads of continuity can be traced in England from workshops in the late sixteenth century to large-scale manufacturers in the late nineteenth century. These threads are represented by chains of apprenticeship. Even new instrument manufacturers like the Cambridge Scientific Instrument Company in the 1880s were reliant on the skills and resources of established instrument firms.

There are many ways in which students could do assignments or projects in relation to historic scientific instruments. There are many aspects to consider in examining the design and function of instruments. How did the instrument work? What is it made of? How was it made? There is an intimate relationship between materials and function. For example, as techniques were developed in the later eighteenth century to produce more accurately divided scales for instruments, then instrument-makers explored the advantages of different metals for the scales.

It is easy to see how a technical assessment of a historic instrument soon leads to questions about the context of manufacture as well as the context of use. What machine tools and techniques could an instrument-maker draw on at any given period in history? What was the relationship between instrument-makers and scientists in the design of instruments? Who were the customers for scientific instruments?

An understanding of some of these issues will enrich discussion of some of the Syllabus Options:

Relate the development of microscopes to the development of cell theory

This Option provides scope for looking at the difficulties in manufacturing high-resolution compound microscopes, how the optical problems were significantly diminished in the 1830s, and how this

enabled the focus of physiology to shift from tissues to cells. The difference between microscopes in the 1660s and 1830s underpins the difference between Robert Hooke's concept of 'cell' and that of the German physiologists of the late 1830s. That there was not a steady development of 'the microscope' in the intervening century and a half opens considerable scope for discussion of the relation between scientific ideas, technical skills and broader social issues.

Discuss the life, times, and achievements of Newton

While Newton's ideas can be presented in a way largely devoid of history, this Option is not complete without a consideration of instruments.

Trace the development of ideas about electricity and replicate historical experiments and debates

The bicentenary of Volta's discovery (or invention) of the electric battery (Voltaic pile) in 1799 provides a focus for looking at the complicated relation between the technology of electrical production and concepts of electricity. The history of the production, storage, distribution and application of electricity provides ample scope for looking at historic instruments and their makers.

The role of scientific instruments is equally important in several other Options such as those concerned with heat and air pressure.

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In the last 20 years a number of factors have led to an expanding range of publications dealing with historic scientific instruments. The Scientific Instrument Commission, a section of the International Union of History and Philosophy of Science, was established in 1977. It has held annual symposia since 1981 which provide an opportunity for specialists in historic instruments to meet and share their research. Proceedings of several meetings have been published (including de Clercq, 1985; Blondel, 1989). Shorter accounts of other meetings have been reported in the *Bulletin* mentioned below.

In 1983 the Scientific Instrument Society was founded in England. The Society has an international membership of museum curators, historians of science, collectors and specialist dealers. The quarterly *Bulletin of the Scientific Instrument Society* is a rich source of information on individual types of instrument, collections and instrument makers. A separate index to the first 50 *Bulletins* was published in 1997. There are also specialist societies concerned with specific types of instrument, such as telescopes, calculators, weighing scales and sundials, which

produce journals and newsletters. Another journal, *Rittenhouse, Journal of the American Instrument Enterprise*, was founded in 1986 and appears quarterly. An index to volumes 1 to 12 has been published in Vol. 13, No. 1 (June 1999). These journals are not readily available in libraries.

Mainstream journals in the history of science are more readily available in academic libraries. These sometimes contain articles relating to the manufacture and use of scientific instruments. In recent years *Annals of Science* has included several major articles on various aspects of instrument history. Of more immediate relevance for discussing the history of instruments in the classroom is an extensive series of articles Thomas B. Greenslade, Jr. has published in *The Physics Teacher* since the 1970s on historical examples of classroom apparatus. Greenslade has published similar articles in *Rittenhouse*. A number of museums have published detailed catalogues of their collections. The Whipple Museum of the History of Science in Cambridge, England, has been particularly productive in publishing catalogues of particular collection areas and informative booklets accompanying temporary exhibitions. Some of these may be available in academic libraries. An extensive series of small booklets on collectibles and historical subjects has been issued by Shire Publications. A number of these 'Shire Albums' are relevant to instrument history (Graham, 1979 and 1981; Greenacre, 1986; Harley, 1988; McConnell, 1988; Scott-Scott, 1986; Watson, 1995). Some titles are available in larger bookshops and antique centres and would be suitable for purchase by school libraries.

A useful introduction to instruments was published by G. Turner in 1980. This may be available in some libraries. A revised edition has recently been published (G. Turner, 1998) which should be considered for purchase by the school library. For instruments before 1800 there is a comprehensive survey which draws on the extensive scholarly literature of recent decades (A. Turner, 1987). Most of the instruments students are likely to see in museums in Australia date from the nineteenth and twentieth centuries. This offers a rich field for studying the development of laboratory research apparatus. An informative and well illustrated guide to nineteenth century instruments (G. Turner, 1983) will be useful for teachers and students to consult.

As an instrumental science, most histories of astronomy give some attention to telescopes. Histories of a number of individual observatories have been published. The standard history of the telescope remains King, 1955. An accessible and well illustrated account of instruments used in **astronomy, navigation and surveying** is Bennett, 1987. The important issue of angular measurement in positional astronomy is examined by Chapman, 1990.

There are a number of books on historic **drawing instruments**. The best guide is Hambly, 1988. A brief introduction is given by Scott-Scott, 1986. Accounts of two copying instruments are given by Hammond, 1981 (the camera obscura) and Hammond and Austin, 1987 (the camera lucida).

The **microscope** has a long history and is used in a broad range of scientific disciplines. Microscopes have therefore been made in large numbers and in a wide variety of designs. Many different kinds of accessories and techniques have been used in conjunction with microscopes. This is reflected in an extensive historical literature. A good introduction to the history of the microscope is Bradbury, 1967. For an accessible visual introduction to the variety of microscopes in the past, Turner, 1981, is particularly good. Gerard Turner has published extensively on historic microscopes. His catalogue of the Royal Microscopical Society collection (Turner, 1989) contains a wealth of detail. Early microscopes presented significant optical problems - not just chromatic and spherical aberration, but variations in the optical density of the optical glass - and so until the 1830s many scientists preferred to use simple rather than compound microscopes. Brian Ford (1985) has conducted practical experiments on historic simple-lens microscopes. A number of academic studies of seventeenth century microscopy have been published recently, including Fournier, 1996. Improvements in the compound microscope in the nineteenth century had a major impact on the development of biology and were accompanied by the development of diverse accessories and techniques for specimen preparation. Bracegirdle has published an extensive survey of the development of microtomes and associated microtechnique (1987) and has provided useful notes on microscopical mounters (1998).

Several of the most substantial historical studies on thermometers, barometers and other instruments used in **meteorology** have been published by W.E. Knowles Middleton. As scientific instruments with a large domestic as well as strictly scientific market, barometers have been made in relatively large numbers since the eighteenth century. Early barometers are today expensive and collectible. Several guidebooks on various aspects of historic barometers have been published (including Bolle, 1984; Goodison, 1977). McConnell's study of J.J. Hicks (McConnell, 1998) provides informative background on the manufacture of thermometers.

For background on historic instruments used in the various branches of **physics**, older textbooks are often helpful. There are a number of catalogues in English of physics collections covering mechanics, acoustics, optics, heat, electricity and magnetism and so on (such as Turner, 1996; Lagemann, 1983). A useful introduction to the development of electrical measuring instruments has been published by the London

Science Museum (Stock and Vaughan, 1983). Before the development of means for producing electrical currents, electrostatic generators - forerunners of the Wimshurst machine - were used in scientific experiments and demonstrations. A comprehensive account has been published (Hackmann, 1978).

The pioneering study by Daumas on instruments and **instrument-makers** was originally published in French in 1953. It was translated and revised by Mary Holbrook. It is valuable for its consideration of Continental as well as English instrument-makers. There is a growing literature on instrument-making in England. For the early period Taylor, 1954, remains a useful reference. A book on the Elizabethan instrument-maker Humphrey Cole was published in conjunction with a recent exhibition at the British Museum (Ackermann, 1998). For the eighteenth and early nineteenth centuries Taylor, 1966 is a useful compendium. A directory of English instrument-makers up to 1850 (Clifton, 1995) is useful for identifying makers, especially those outside London not well covered in other references. A number of studies have been produced on individual makers or firms in the eighteenth and nineteenth centuries: Benjamin Martin (Millburn, 1976, 1986), R.B. Bate (McConnell, 1993), J.J. Hicks (McConnell, 1998), Cooke, Troughton and Simms (McConnell, 1992), the Cambridge Scientific Instrument Company (Cattermole and Wolfe, 1987). A comparative study of the industrial production of instruments in Britain and France in the late nineteenth and early twentieth centuries would have been strengthened by a greater consideration of German industry (Williams, 1994).

There are studies of instrument-making in Scotland (Bryden, 1972; Clarke, Morrison-Low and Simpson, 1989) and Ireland (Burnett and Morrison-Low, 1989). The important Irish telescope maker, Thomas Grubb (who made the Great Melbourne Telescope), is the subject of a recent study (Glass, 1997). Accounts of American instrument-making are given by Bedini (1964; 1975). Studies of some French and German instrument-makers have been published. Numerous shorter studies of instrument-makers appear in journals, including the *Bulletin of the Scientific Instrument Society*.

For people wishing to follow more specific themes, further bibliographical references will be found in books listed here. A broad ranging guide to literature on historic instruments published between 1980 and 1995, conveniently organised into categories, is inexpensively available from the Museum of the History of Science in Oxford (Turner and Bryden, 1997). A supplement to this bibliography is available on the Scientific Instrument Commission's web site.

The following bibliography is by no means exhaustive. It is intended to

provide a guide to the more substantial literature on historic scientific instruments. While many of these books will not be readily available in libraries, quite a number of them are in print or have recently been reprinted.

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WEB SITES

While many of the books referred to will not be readily available, a growing quantity of information about historic scientific instruments is accessible on the Web. An increasing number of museums with historic scientific instruments have web sites. The following is intended as a guide to some of the sites which have more extensive or detailed information about instruments.

A significant number of historic instruments in Australia are held within universities. Basic catalogue information on several instrument collections is available through **Australian University Museums On-Line**: <aumol.usyd.edu.au>. This includes the collections of the **Macleay Museum**, Sydney, and the **Physics Museum** at the University of Queensland. These each have their own web sites:

<<http://www.usyd.edu.au/myweb/>> and <www.physics.uq.edu.au/physics_museum/index.shtml>. This latter site contains good illustrations and descriptions of instruments covering optics, geophysics, metrology, electricity, electronics, computing, acoustics, and X-rays; also details of the Brisbane clock manufacturer, Synchronome. **Australian Museums On-Line** provides access to information about museums throughout Australia: <amol.org.au>.

Information derived from searching these sources may suggest opportunities for class visits or student projects. Some overseas sites contain excellent detail which could form the basis for student assignments. For example, in the course of a discussion about Galileo it is now possible to make a virtual visit to Florence to see his instruments: <galileo.imss.firenze.it/museo/4/welcome.htm>. These are held in the **Institute and Museum of the History of Science** which holds an extensive and significant collection of instruments: <galileo.imss.firenze.it>. This site now features an extensive presentation about Evangelista Torricelli and the discovery of the weight of air.

The **Museum of the History of Science** in Oxford is housed in the original Ashmolean building erected in the 1680s. In embodying scientific traditions going back to the scientific revolution, it is a fitting home for one of the major collections of historic scientific instruments in the world. It maintains an excellent home page <<http://www.mhs.ox.ac.uk/>> which has several on-line exhibitions and also includes links to other sites.

The **École Polytechnique**, Paris, is developing a web site which is now partially available in English:

<www.polytechnique.fr/bibliotheque/CollectionGB.html>. It provides good illustrations of instruments with some descriptive text. The on-line selection of scientific instruments includes acoustics, electricity and magnetism, weights and measures, optics and chemistry. There is also good background on scientists and instrument makers. The Institut National de Recherche Pédagogique in France has developed **An inventory of old scientific instruments in State Schools:**

<www.inrp.fr/she/instruments/winstruments.htm>. The link goes to an English version of the introductory text (also available in French) but the individual descriptions are in French. In a project to locate and inventory old scientific materials preserved in many schools in France, more than 1200 old instruments in 130 lycées and teacher training colleges have been listed and described in full detail. This work will shed new light on the development of science teaching from the 18th century to today.

The Stewart Museum in Montreal, Canada, has a collection of physical demonstration apparatus representative of the work of the eighteenth century physicist, the **Abbé Jean-Antoine Nollet**: <www.stewart-museum.org/table2.htm>. A preliminary inventory of **Lavoisier's instruments** preserved at Musée des arts et métiers in Paris is now available (together with other collections related to the French chemist) at the website <moro.imss.fi.it/lavoisier>. A printed version of the catalogue is in preparation.

A number of North American sites are likely to be especially useful for student projects. **Humboldt State University** in California has a virtual museum: <www.humboldt.edu/~rap1/MuseumProject/museum.shtml> devoted to twentieth century instruments used at the University.

"Whenever possible the following information is provided for each instrument: 1) a photograph, 2) a brief paragraph on the usage and history of the instrument, 3) a detailed description of the instrument including its current condition, and 4) a scanned image of a contemporary vendor's catalogue description of the instrument.

Additional information may include the following: brief histories of manufacturers, contemporary and/or early descriptions of the instruments and their usage, documents pertaining to the specific instruments, and more detailed histories of the invention and development of select instruments." The **Peabody Museum at Yale University** also has a collection of instruments for which some information is available on-line:

<<http://www.peabody.yale.edu/collections/hsi/>>. The **University of Toronto** is setting up a **Museum of Scientific Instruments:**

<<http://www.chass.utoronto.ca/utmusi/>>. The Department of Physics and Astronomy at the **University of Nebraska, Lincoln**, has a well organised **Historical Scientific Instrument Gallery:**

<www.unl.edu/histinstr/>.

There are also sites for more specialised interests. All the medieval and renaissance scientific instruments held by the Museum of the History of Science in Oxford, the Istituto e Museo di Storia della Scienza in Florence, the British Museum in London and the Museum Boerhaave in Leiden are now documented in an on-line catalogue. **Epact: Scientific Instruments of Medieval and Renaissance Europe**, hosted by the Museum of the History of Science in Oxford, was launched in May 2001: <www.mhs.ox.ac.uk/epact>. "It is aimed at both the general public and the connoisseur of scientific instruments. Each instrument in the catalogue is described by an overview text and a detailed technical description as well as being illustrated by photographs. Supporting material for the catalogue includes an essay on the Medieval and Renaissance mathematical arts and sciences, articles describing the function of different instrument types, entries on makers and places represented, a glossary of technical terms, and a bibliography."

A catalogue of medieval Islamic and European astronomical instruments is currently being prepared at the Institute for the History of Science at Frankfurt University: <www.uni-frankfurt.de/fb13/ign/instrument-catalogue.html>. It is intended that the **Catalogue of Medieval Astronomical Instruments to ca. 1500** will serve as a useful research tool by providing critical descriptions of all historically significant instruments, arranged according to provenance and type. The total number of instruments included in the catalogue will be about 550 astrolabes (some 300 Islamic and 250 European) and 250 quadrants, sundials and other instruments.

Numerous collections include microscopes. The **Moody Medical Library** at the University of Texas in Galveston has a specific Microscope Collection: <library.utmb.edu/Blocker/Microscopes/>. "The historical microscope collection housed in the Moody Medical Library is considered one of the major collections of its type owned by an academic institution in the United States. The collection consists of representative samples documenting the development of microscopy from the 18th through the first quarter of the 20th century. The work of more than 30 individual makers or firms is included." The University of California at Berkeley recently received a significant donation of eighteenth and nineteenth century microscopes known as **The Golub Collection**. These are all illustrated and described at <ib.berkeley.edu/golub>. A web site devoted to the **History of the Light Microscope** can be found at <www.utm.edu/personal/thjones/hist/hist_mic.htm>.

Surveying instruments are also represented. Apart from surveying

instruments in broad-ranging collections there are specialist web sites. The **Virtual Museum of Surveying** is at <www.surveyhistory.org/>. The **National Museum of American History**, part of the Smithsonian Institution in Washington, has a site devoted to its Surveying and Geodesy collection: <americanhistory.si.edu/surveying>. This contains information on numerous instrument makers as well as a catalogue of specific instruments. The Istituto Tecnico per Geometri "L.Nottolini" in Lucca, Italy, has a **Collezione Storica Strumenti Scientifici e di Topografia**: <www.lunet.it/Lucca/ITG/topograf.htm>. There is a modest **Surveying Instrument Collection** at the University of New South Wales, Sydney: <www.gmat.unsw.edu.au/final_year_thesis/f_pall/html/welcome.htm>.

Italian collections have been well documented in recent years. As a counterbalance to English and American sites some of the following are worth investigating. An Italian **Collection of Historic Electrical Instruments** is available in English at <www.iem.it/museum/museum.html>. The Museum of Scientific Instruments in the Physics Laboratory at the **University of Urbino** has a well presented Web Page: <www.uniurb.it/PhysLab/Strumenti.html>. The Museum of the Department of Physics at the **University of Naples** has a number of photographs with explanatory text in Italian and at present a smaller selection in English: <www.na.infn.it/Museum/Museo.html>. The site includes instruments associated with Macedonio Melloni. An extensive selection of images with limited documentation (in Italian) in the physics section of the **Museum for the History of the University of Pavia** is worth visiting: <chifis.unipv.it/museo/fonti/museo/fisica/museo.htm>. One of the most important scientists associated with the University of Pavia was **Alessandro Volta**. Information about Volta's life and instruments can be found at <File-server.cilea.it/Museo/Pages/ePage0.html>. The **Museo della Specola** in the Department of Astronomy at the **University of Bologna** has excellent photographs of nearly 100 historic instruments relating to astronomy and time, together with substantial commentaries (in Italian): <<http://www.bo.astro.it/dip/Museum/italiano/fronte.html>>.

The **Hellenic Archives of Scientific Instruments**: <www.eie.gr/hasi/> is a site (in English) being developed to document historic instruments in Greek collections. There are excellent photographs but limited information so far.

Montclair State University in New Jersey has a web site devoted to a **Museum of the History of Psychological Instrumentation**: <chss.montclair.edu/psychology/museum/museum.html>. This is entirely a virtual museum in that it does not illustrate actual instruments but is based on illustrations in a 1903 Zimmermann

catalogue. For photographs of psychological instruments turn to the **Psychology Collections** of the University of Toronto: <psych.utoronto.ca/museum> and the Barnard College Psychology Department of Columbia University, New York: <www.columbia.edu/barnard/psych/b_museum.htm>.

The Adler Planetarium & Astronomy Museum in Chicago hosts an extensive **database of instrument makers' names** compiled by Rod and Madge Webster over many years: <www.adlerplanetarium.org/history/websters/welcome.htm>. It is described as an aid to research rather than an authoritative reference. While it will no doubt continue to be refined in coming years it is a remarkably extensive listing of scientific instrument makers with bibliographical references and notes of existing instruments. It is thus a very good starting point for finding information, especially about the less familiar makers.

The **Scientific Instrument Commission** page, including bibliography, is at <http://www.sic.iuhps.org/>. The **Scientific Instrument Society** page is at <http://www.sis.org.uk/>. **The Gemmary** is a dealer in antiquarian books and instruments. It maintains a website that includes information on the availability of reference books: <http://www.gemmary.com/>. This also includes a discussion forum: www.gemmary.com/insts/forum/forum.shtml. The journal *Rittenhouse* has introduced a regular column of 'Web Sightings and Reviews' by Dana A. Freiburger (from vol. 13, no. 1, June 1999).

There are a number of specialist societies that now have web sites

The Antique Telescope Society: <www1.tecs.com/oldscope/>

The British Sundial Society: <www.sundialsoc.org.uk/>

The North American Sundial Society: <www.sundials.org/>

Sundials on the Internet: <www.sundials.co.uk/>

MUSEUMS TO VISIT

Note: Teachers planning class visits to museums should make prior bookings.

There are a number of museums in Australia which have historic scientific instruments on display. The **Powerhouse Museum** includes

instruments in several exhibitions including Experimentations. A considerable number of instruments associated with astronomy and meteorology are on display at **Sydney Observatory**, near the Sydney Harbour Bridge. Navigational instruments can be seen in some displays in the **Australian National Maritime Museum** in Darling Harbour.

At the University of Sydney, a number of museums and collections hold scientific instruments. The principal of these is the **Macleay Museum** which features instruments in several displays, especially microscopy and surveying. There is also a small **Psychology Museum** located near the Maclaurin Hall which includes a variety of physiological testing instruments.

The **Museum of the History of Science** at the University of New South Wales is located in the Chemistry School and features a range of mainly laboratory instruments. In the School of Geomatic Engineering nearby is a small display of surveying instruments only accessible by prior arrangement.

The **La Perouse Museum** at Laperouse, run by the NSW National Parks and Wildlife Service, features a variety of instruments relevant to the voyage of La Perouse. The Museum is well worth visiting and would form a good backdrop to a discussion on European science and exploration in the late eighteenth century. The La Perouse Museum is located in the old cable station erected for the telegraph cable connection to New Zealand in the 1870s. This is also featured in a display.

One or two instruments are commonly to be found in country museums. Of special note is the **Museum of Jervis Bay, Science and the Sea**, part of the Lady Denman Heritage Complex at Huskisson. This features the most extensive array of historic navigational instruments on display in Australia as well as surveying instruments. The **Land Information Centre** in Bathurst (NSW Department of Land and Water Conservation) has a foyer display of historic surveying instruments.