cal method, the Cusa-Snell refinement, continued fraction expansions, infinite products and infinite series methods, π by probability, and Monte Carlo procedures are clearly explained. The mathematics is not slighted and is generally elementary; a reader can safely skip any passages he may find too taxing. The book ends with the citation of a few cases of *morbus cyclometricus*, the circle-squaring disease.

Claiming that the history of π "is a quaint little mirror of the history of man," Beckmann holds up the mirror to the reader by giving some of the background of the times under discussion. He sees the men who make history forming two opposing classes—the thinkers and the thugs. For example, the Greeks were thinkers and the Romans were thugs. The basic law seems to be that the thugs always win, but the thinkers always live longer. As a Czech (though now living in the United States), Beckmann is very conscious of the existence of thugs.

The book has some shortcomings: It is marred by a couple of dozen careless errors, such as bad hyphenation, the consistent misspelling of Apollonius ("Appolonius"), and incorrect or missing superscripts. There are some historical errors: In his zeal to discredit the Romans (as thugs), Beckmann converts the accidental destruction of the first Alexandrian library into a deliberate act of Roman vandalism. He also reports Archimedes' tomb as still unfound, and, because the Egyptian rope stretchers laid out right angles with a 3-4-5 triangle, he credits them with a knowledge of the Pythagorean theorem. There are some serious errors of omission: Thus, in bringing the computation of π to modern times, Beckmann ends with the 2037-place calculation on the ENIAC in 1949. Omitted are the more recent facts that: (i) in 1959, François Genuys, in Paris, computed π to 16,167 places using an IBM 704; (ii) in 1961, J. W. Wrench, Jr., and D. Shanks, of Washington, D.C., computed π to 100,265 places, using an IBM 7090; (iii) in 1965, Jean Guilloud and his co-workers at the Commissariat à l'Energie Atomique in Paris attained 250,000 places on a STRETCH computer; (iv) exactly one year later, the last group found π to 500,000 places on a CDC 6600. Nor were these extensive machine calculations performed merely because of the challenge or feat involved, but rather to obtain statistical information on the normalcy or nonnormalcy of π. The famous 707-place calculation of π made by W. Shanks in 1873 seemed to indicate that π was not even *simply* normal; this led in 1946 to a check of the computation, revealing errors starting with the 528th place.

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A Wide-Ranging Concept

The Origins of Feedback Control. OTTO MAYR. Translated from the German edition (Munich, 1969). M.I.T. Press, Cambridge, Mass., 1970. viii, 152 pp., illus. \$7.95.

The need for closer communication between scholars in different disciplines is made explicit by this valuable excursion into the history of technology undertaken by a mechanical engineer who is now curator of mechanical engineering at the Smithsonian Institution. Mayr may be said to be "flying a kite" by tracing through history examples of devices that meet his definition of a feedback system: namely one that carries out commands and maintains the controlled variable equal to the command signal in spite of external disturbances, that operates as a closed loop with negative feedback, and that includes a sensing element and a comparator, one of which can be distinguished as a separate physical element. The devices that meet these demands in the author's opinion include Ktesibio's water clock, Philon's oil lamp, and the float valve as used by Heron of Alexandria in the Hellenistic world, and a variety of clocks constructed in the Islamic world during the later middle ages similarly employing float valves. Heron's *Pneumatica*, which revealed a delight in the intellectual quality of the feedback system for its own sake, seems to have been known only in the Islamic world in the early middle ages, but after the 12th century many more manuscripts of the work appeared in Western Europe. Nevertheless the float valve was not used between the 12th and the 18th centuries. Why was this feedback system neglected? Is there here involved some basic change in attitude that makes technological development much slower than it need have been?

According to the author, in the 18th century the number of feedback devices greatly increased, including perhaps the most famous of all, Watt's centrifugal governor, but Mayr also shows that in fields other than technology the same intellectual system was being employed—by Adam Smith in his *Wealth of Nations*, in the political philosophy of "checks and balances," and presumably he might have added Ricardo's wage law and Malthus's theory of population growth. It is part of Mayr's claim, which I hope will be more fully set forth in another book, that the burgeoning of feedback devices in 18th-century England represents a fundamental change in human outlook, in that it involves a reappraisal of what may be accomplished by the machine alone. Having heard so much, almost to boredom, of Newton's clockmaker, one is glad to know that the divine mechanic also made water closets.

The book is clearly illustrated with 72 figures, and block diagrams are used in analysis throughout.

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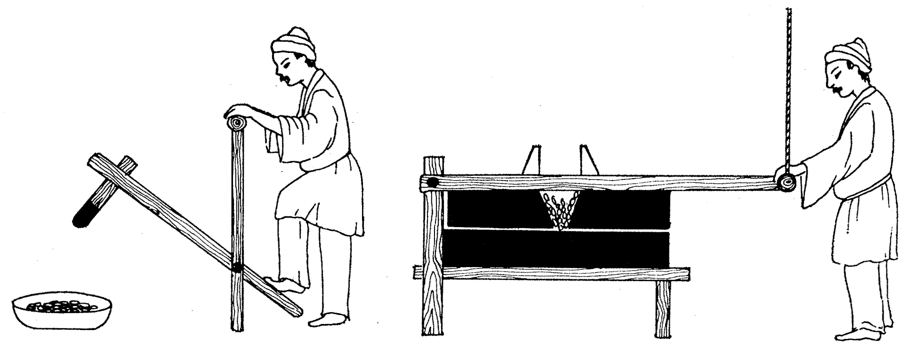
Ingenuity Illustrated

Technology in the Ancient World. HENRY HODGES. With drawings by Judith Newcomer. Knopf, New York, 1970. xviii, 302 pp. \$10.

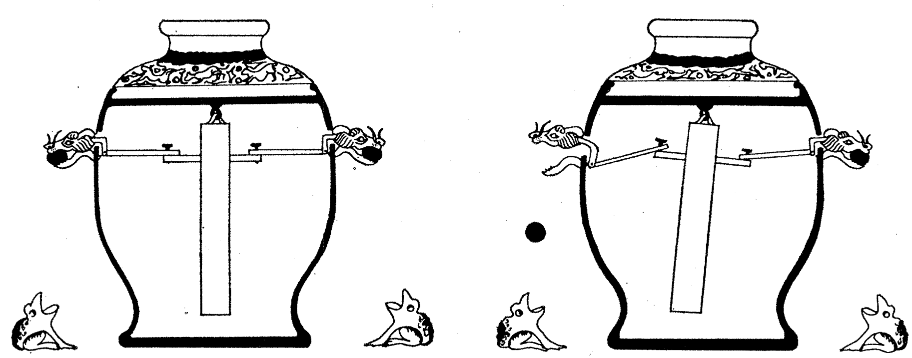
I have found, in teaching courses in history of technology, that engineering students respond with more enthusiasm to the technology of ancient Egypt, Mesopotamia, Greece, and Rome than to the scientific technology of the Industrial Revolution and later. Usually, I think, the excitement follows the discovery of a totally unexpected sophistication, both of equipment and techniques, that is to be found in the early phases of civilized society. Equally intriguing are the advances in masonry construction, metallurgy, glassmaking, woodworking, water raising, and the arts of making textiles, pottery, beer and wine, and a variety of tools of both war and peace.

Yet it is difficult to find text material that will support the notion that our technological heritage is both very broad and extremely deep. Except for Hodges, nobody has yet made a serious attempt to provide, in a work of moderate length, a summary account of tools, techniques, and products of the technologist.

While Hodges's book includes many errors and imperfections, it is a big step in the right direction. It is a readable and copiously illustrated account of the whole array of mechanical, chemical, and metallurgical arts from the first appearance, before 5000 B.C., of tools of traditional form (which is to say that a modern craftsman will recognize what they were used for) until the end of the western Roman empire. His explanations of the way things work are clear, straightforward, and generally accurate. A specialist in any field but Hodges's own—archeology—will find points to deplore. It is noted, for example, on page 118, that several authorities agree that the Great Pyramid was built by 100,000 men working for 20 years. Does the author know that his several authorities have simply accepted the figures recorded by Herodotus when he visited the pyramid as a sightseer *over two thousand years* after its completion? I should suspect that the authority consulted by Herodotus was the donkey driver who guided him about the pyramid complex. Hodges leans too heavily upon secondary works that recount the familiar and simplistic explanations of cause and effect, often falling into patent nonsense; but not as often, I must add, as many other authors do. He reflects also the impatience that present-minded authors display toward ancient inventors who fail for hundreds of years to discover the obvious next step of development.



Two types of mill in use in China before the beginning of the Christian era (diagrams based on documentary sources). The foot-operated hammer mill (left) may have been what inspired the iron-forging hammer driven by a cam on the shaft of a water wheel, which allowed larger forgings than would have been possible with hand-held hammers.



Sectional view of a Chinese seismograph of bronze, probably about A.D. 600. "Seen in the round, the vessel carried on its perimeter a dozen figures of frogs [sic], each with a metal ball held in its hinged jaw. Earth movements would have disturbed the central pendulum sufficiently to release a metal ball, thus showing the direction of the tremor." [From *Technology in the Ancient World*]

A much more careful work, requiring several times the effort that went into this book, is what I should like to see. Drawings can be made much more informative, and pictures can be reproduced in color in such a way that the reader will appreciate their esthetic perfection (for example, a stunning pressure-flaked stone blade); but in a commercial venture my wishes are not likely to be honored.

Nevertheless, this book does give an instructor something upon which to build. In a subject that must lean heavily on pictures and diagrams that have to be studied in order to be understood, it is no small matter to be able to put into a student's hands a sensible collection of 265 pictures with supporting text.

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World Heavyweights

Imperial Chemical Industries. A History. Vol. 1, The Forerunners, 1870–1926. W. J. READER. Oxford University Press, New York, 1970. xvi, 564 pp. + plates. $17.50.

This surely must rank among the very best corporate histories ever written. With deceptive simplicity it reduces to panoramic order the restless technology and organizational gymnastics of 80 or more corporations all struggling for survival in the heroic age of trust formation. Far more than a narrow business history, the book portrays the emergence of the chemical industry as we now know it and, more generally, the birth of the modern corporation, thrust up by irrepressible technical and organizational innovations but uniquely shaped and directed by industrial statesmen whose success in overcoming international barriers stands in sharp contrast to the failures of their political contemporaries.

The wheeling and dealing of these industrialists form the focus of Reader's book. We can take issue with this emphasis, but it is a thoroughly defensible approach, particularly if, as Reader intends, the book is to be widely read and not just consulted as a reference.

The book begins with the extensive technical reorientation of the chemical industry that began in the 1870's as a consequence of three scientific and technical innovations: dynamite, Solvay soda, and coal tar dyes. Nobel's dynamite and the smokeless powder he helped to develop a decade later reduced the sale of old-fashioned black