Physical Sciences and Engineering in China

It is frustrating to have to review, in only a few hundred words, these two large and richly illustrated volumes: **Science and Civilisation in China**, vol. 4, pts. 1 and 2 [Cambridge University Press, New York, edited by Joseph Needham with the collaboration of Wang Ling and (for part 1) the special cooperation of Kenneth Girdwood Robinson].

The appearance of the volumes brings roughly to the halfway mark this unprecedented survey, by no means confined solely to China, of man's efforts to understand and utilize the cosmos to which he belongs. In instance after instance, the results are as important and unexpected for historians of Western science as for those of China itself.

Part 1, *Physics* (1962, 434 pp., $16.50), of the fourth volume, *Physics and Physical Technology*, begins by pointing to a fundamental philosophical distinction: the Chinese viewed the cosmos as a single organic continuum, in contrast to Westerners (and Indians), who viewed it as built out of an infinity of discontinuous atoms. From this the book goes on to discuss dynamics, heat, optics, acoustics (particularly the Chinese musical search that led in the 16th century to discovery of the equally tempered scale), and finally the fascinating story of Chinese progression from geomancy to lodestone, from lodestone to magnetic compass, and eventually to the latter's application to navigation, in which form it was transmitted to the West.

In Part 2, *Mechanical Engineering** (1965, 757 pp., $35), we read successively about basic mechanical principles (levers, wheels, cranks, and the like), agricultural implements and machines, vehicles, animal traction (efficient as against inefficient harness), water-raising machines, watermills and windmills, paddle boats, Chinese clockwork (including the all-important invention of the escapement), and the prehistory in East and West of aeronautical engineering.

Some of these topics, for example, the magnetic compass or the clock, fully deserve the hundred or more pages allotted them. Others, such as "the revolving bookcase in East and West," seem somewhat trivial and remote from the main story. In these volumes, as in others of the series, a major and no doubt inevitable difficulty, despite the remarkable lucidity with which their material is presented, is that of retaining overall perspective in the face of masses of individually interesting but collectively sometimes overwhelming detail.

The author, with understandable annoyance at the traditional Western self-complacency concerning science, never fails to emphasize—perhaps he sometimes overemphasizes—the numerous instances of Chinese priority in technological development. His general conclusion, reached at the end of part 2, is that "the only important basic machine which the Chinese did not have was the continuous screw," and that "the balance shows a clear technological superiority on the Chinese side down to about A.D. 1400." These statements, though apparently valid, raise certain broad questions which Needham himself does not here attempt to answer. (No doubt he will do so in his seventh and concluding volume on the social and economic background of Chinese science.)

Take, for example, the popular notion that Chinese technology, unlike that in the West, was inhibited by over-reliance on abundant and cheap manpower. This notion is scarcely substantiated by the fact, demonstrated by Needham, that China, before the birth of Christ, had already devised a form of breast-strap harness enabling its horses to draw loads several times as heavy as those drawn by European horses, whose throats were choked by the throat-and-girth kind of harness universally used in Europe until around the 9th century A.D. On the other hand—and this is a point not mentioned by Needham—this same China, from the 4th century A.D. onward, was also home of the exclusively manpowered sedan chair, a "contribution" that it transmitted to Europe in the 17th century.

Or again, there is the phenomenon repeatedly recorded in these pages, namely, the initial invention of a technique in China, where, however, it undergoes little further evolution and perhaps is even forgotten, whereas when passed on to Europe, the technique may there set in motion further developments of the utmost consequence. This is strikingly illustrated by the history of Chinese and Western clockwork. In China, complex mechanisms for keeping time, utilizing the escapement principle, date back at least as early as the 8th century, and continued to be constructed for many centuries thereafter. In Europe, on the other hand, the idea of the escapement appeared only around 1300. Yet by the time the Jesuits arrived in China around 1600, bringing Western clocks, the indigenous tradition of clockmaking had so declined that it was possible for the Jesuits to persuade all but a few Chinese scholars that these Western clocks represented an entirely new principle in China. In fact Matteo Ricci himself (under his Chinese name of Li Ma-tou) was deified as the tutelary divinity of later Chinese clockmakers.

The answer to this paradox, almost surely, lies in the strongly governmental-bureaucratic orientation of much Chinese technology. The Chinese escapement "clocks" of pre-Jesuit times, for example, were astronomical in inspiration, and built for imperial use only. They consisted of tower-like structures housing large water wheels that, by means of gearing, slowly rotated armillary spheres and celestial globes, and at the same time operated apparatus for visibly and audibly telling the time. Thus, their primary purpose was ritualistic: the maintenance of cosmic harmony between man (exemplified by the emperor) and the universe, by means of man's accurate observation and imitation of cosmic phenomena.

This cosmo-governmental stimulus for the Chinese mechanisms meant that they were always few in number (and for centuries it was legally forbidden for private individuals to possess celestial globes and similar astronomical apparatus), which in turn meant that the tradition of building them could at any time be easily bro-

* Part 2, *Mechanical Engineering*, will be available from Cambridge University Press, New York, in the fall.

ken by dynastic change, foreign invasion, or other unfavorable political factors. In Europe, on the other hand, where the social and ideological background was quite different, the making of clocks (and later watches) could readily develop into a mass enterprise. As Needham himself points out, " . . . clock-making in China seems never to have become a mass industry before the time of the Jesuits (as it did in 15th- and 16th-century Europe)."

We look forward with keen anticipation to the appearance of part 3 of volume 4 (on civil engineering and nautical technology), as well as the projected three later volumes.

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Periodic Phenomena

Biological Rhythm Research. A. Sollberger. Elsevier, New York, 1965. xx + 461 pp. Illus. $25.

During recent years research on biologic rhythms has grown in volume and scope. Thus, temporal biology and medicine have become interdisciplinary fields. The physical, mathematical, and engineering sciences have contributed significant techniques and theories that facilitate the quantification of biologic rhythms and, thereby, the endeavors directed toward an understanding of the temporal coordination of physiologic functions as a whole.

The book here reviewed, *Biologic Rhythm Research*, constitutes a general survey of research on periodic phenomena within the animate world. The accents of presentation are placed on theoretical considerations intended to pertain to problems of analysis and to questions revolving around the factors underlying biologic rhythms. The topics discussed include principles of physics and engineering applicable to periodicity, the mathematical and statistical treatment of cyclic functions, cybernetics, and models of biologic rhythms. Applied research on biologic periodicity is referred to in the last chapter. An extensive bibliography accompanies the text.

The material covered in this well-organized, single volume is enormous. The elements of theoretical considerations are presented in the form of an outline, which does not communicate enough information for a thorough understanding of the complexities on hand. The selection of the material included and discussed is somewhat subjective. The author refrains from critical discussion. Unfortunately, "synonyms" for specific terms are used in a confusing fashion. Oscillatory instability in servomechanisms is not necessarily a vicious circle (Fig 1.12d), a square wave-shape does not define an impulse (Fig 1.30a), nor is feedback energy generally supplied by an amplifier (Section 2.25).

A multidisciplinary approach to biologic rhythm research requires familiarity with the scientific background of a diversity of theories and methods, and it requires clarity in the interpretation of terminology contributed by the various disciplines. Omissions along this line contrast with the intention of the book "to offer comprehensive information on biologic rhythm research, but also to provide a basic understanding of future problems."

This diligent and laborious volume is not a textbook for students and researchers starting work on rhythmic functions. It is recommended to the critical specialist in the field as an outline that provides an extensive and most helpful bibliography.

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Comprehensive Botany Text

Strasburger's Textbook of Botany. Rewritten by Richard Harder, Walter Schumacher, Franz Firbas, and Dietrich von Denffer. Translated from the 28th German edition (Stuttgart, 1962) by Peter Bell and David Coombe. Longmans, Green, London, 1965. xviii + 846 pp. Illus. 84s.

Although the major divisions of this text are nearly the same as those of the previous English version, which was published 35 years ago, the content has been greatly improved. In Morphology, the first of four parts, highly diverse subject matter is loosely integrated under such topics as cell size, possible isomers of polypeptides, electron micrograph of a root-tip cell, crystals in cells, interspecific grafts in the alga *Acetabularia* showing the role of the nucleus in determining the morphogenesis of cap regions, mitosis, meiosis, fine structure of cell walls, characters of tissues, morphology and anatomy of the plant body, reproduction, evolution, and grades of morphological organization; in all, this part is ultimately subdivided into 78 subject headings. Within the last-named topic the telome theory is presented lucidly. Anatomical descriptions and gross and microscopic drawings of mature plant organs are dominant, but developmental sequences in the origins of leaf, root, and stem apex are also presented.

Physiology in this text covers not only water relations, mineral nutrition, carbon dioxide assimilation, respiration, protein metabolism, translocation, and secretion but also growth of cells and organs and the transport of growth substances. Movements in plants, influence of environmental factors on plant development, photoperiodism, and heredity are also placed here. The biochemistry of many metabolic steps in higher plants and more universal sequences such as the citric acid cycle are given fairly complete treatment. Osmotic relations are presented more from the biologic than from the physicochemical viewpoint. Auxins are given very brief treatment, and leaf abscission is not correlated with auxin gradients. Kinetin is only mentioned, and the actions of gibberellin are briefly reported in widely separated contexts. Cell, tissue, and organ cultures are not discussed; phytochrome is not treated in appropriate contexts, nor is it in the index.

In the part on systematics, a survey of every major plant group is attempted, resulting in scant coverage of most. A redeeming feature is the survey that follows each division. A more complete presentation of at least one representative within each subdivision would be useful; such a beginning was made with *Funaria*.

Obviously the fourth part of the book, Plant Geography, is again too inclusive. Its second subpart concerns plant communities and would fit better under the heading "Ecology," a word that is used only a few times. Largely ecological are the discussions of succession and the life forms of Raunkiaer (the latter is located in the first part).

A list of references is appended, but only by inference is it possible to correlate superscripts at chapter headings with literature lists that are heavily weighted with older monographs. Owing to its main headings and the index entries this book appears to be more conservative than it really is. True, many topics lack the dynamic or action-spectrum approach, but enough of the experimental bases are alluded