Four hundred years of revolutions in science

The Heritage of Copernicus: Theories "Pleasing to the Mind"

J. Neyman, ed.
542 pp. MIT Press, Cambridge, Mass., 1974.
$25.00

Reviewed by Richard Berendzen

Nicholas Copernicus (top) and six later scientific "revolutionaries": (clockwise, from left) Georg Cantor; Orville Wright; Albert Einstein; Wendell Stanley, the Countess of Lovelace and Edwin Hubble. Each of the seven was responsible for a highly novel scientific development.

In 1473, Mikolaj Kopernik was born in Torun, Poland. In 1973 the National Academy of Sciences sponsored an international celebration in Washington, D.C. for the Copernicus Quinquecentennial—whence the extraordinary volume under review.

As Harrison Brown notes in the book's preface, "The epoch when it was possible for individuals to acquire a reasonably detailed view of practically all of science is now far behind us." Nonetheless, editor Jerzy Neyman, a professor of statistics at Berkeley, has gone far here to implement such Leonardian comprehension. His introduction provides a useful background on Copernicus, including such tidbits as Copernicus's anticipation of Gresham's law by three decades. Although Neyman's account is generally impeccable, his assertion that Copernicus was in a sense the first modern scientist disagrees with recent analysis.

Copernicus is better thought of as closing the past than opening the present. For this book, however, the most pertinent aspect of Neyman's essay is his definition of Copernican and "quasi-Copernican" revolutions. Not surprisingly, considering the tomes that have been written on this subject, Neyman's brief account is not entirely satisfactory. But irrespective of their merits, his definitions are used throughout the volume: He posits that a quasi-Copernican revolution is highly significant yet confined to a scientific subdomain, with at most a moderate "domino effect."

The remainder of the book is composed of 24 essays by distinguished living scientists on post-Copernican scientific revolutions, exploring whether these later developments were in fact revolutionary. The subjects of these analyses include such giants as Bohr, Darwin, Mendel, Planck, Riemann and Shapley. And the authors include such luminaries as Bart J. Bok, Harrison Brown, Glenn T. Seaborg, and H. Guyford Stever. The melange of topics are grouped under six basic headings: Astronomy and Cosmology (4 essays), Biology (6), Chemistry and Physics (4), Mathematics (3), Statistics (3) and Technology (4). Although the authors generally succeed in instructing, some sections will be fully understandable only by the elusive "educated layman," who also presumably consumes *Scientific American* regularly. The essays overall are extremely enjoyable, sometimes provocative, often informative, and rarely disappointing. The styles of writing, however, are as idiosyncratic as the authors and topics themselves. Some essays are in the first person, while others read like miniature textbooks.

Despite its strengths, the volume nonetheless has unfortunate weaknesses. Although the authors are outstanding in their scientific areas, few are historians of science. The accounts here tend more to be anecdotal than scholastic: Several essays contain no documentation and the ones that do, refer almost exclusively to secondary rather than primary sources. Thus even though these accounts are valuable, ironically most of them probably would not have been accepted for publication by a tightly refereed journal in the history of science. This book nonetheless serves a useful role by giving important contributors' perspectives on significant scientific developments, in which some of them actually participated.

The section "Astronomy and Cosmology" illustrates some of the strengths and weaknesses of the entire volume. From his intimate knowledge of the subject, Bok lucidly describes the controversy in the early part of this century

about the Sun's location in the Galaxy.

The second astronomical essay is on Edwin Hubble's extragalactic research. Even a discovery as monumental as the expanding universe could not rightly be called Copernican, although it might fit Neyman's definition of quasi-Copernican. However, the next two astronomical essays—on explosive events and modern riddles in cosmology—are, if anything, proto-Copernican. The entire volume consists of such an epistemological and philosophical jumble. But even though the book's elucidation of post-Copernican revolutions may not be impeccable, it provides a fine précis on highly significant and novel developments in many sectors of science.

For instance, David Hubel claims that neurobiology has never had a Copernican revolution; and if it ever does, the effect will doubtless be gradual, spreading over decades. And he adds that the one great remaining question of science is "whether or not [the mind] is something more than a machine of great complexity." Seaborg, however, asserts that the "evolution of the whole field of the transuranium elements ... constitutes a real Copernican revolution." Although his account is engrossing, his evaluations of the field's long-term philosophical importance surely is overstated.

Several authors lamely attempt to weave their disciplines into the Copernican mosaic. In his pedagogically stunning essay on relativity theory, Rainer K. Sachs attempts to liken special relativity to Copernicus's heliocentricism and the Michelson and Morley experiment to Ptolemy's epicycles. Victor F. Weisskopf, in contrast, in an elegant essay on quantum theory, simply ignores the Copernican theme: he gives the facts, allowing the reader to make his own metaphors.

Besides philosophy, memorable miscellanea are sprinkled throughout the volume. We learn that the world's first computer programmer—Lord Byron's daughter, the Countess of Lovelace—lost her fortune betting on an "infallible" mathematical system for horse races. And Student's t-table came from W. S. Gosset, a chemist in the Guinness Brewery, who wrote under the pen name of "Student."

Many contributors use seductive pedagogical techniques and provide subtle insights. Stever, after rightly noting the supreme significance of the Wright brothers' first flight, ranks it as non-Copernican; instead, he calls Cayley, of a century earlier, the "true inventor of the airplane." Robert L. Carman, writing on lasers, astutely shows that breakthroughs can be evolutionary rather than revolutionary. But he fails to note the evolutionary nature even of the Copernican revolution: In a sense it was started by Aristarchus, aided by medieval anti-Aristotelians, accelerated by Copernicus, facilitated by Tycho and Kepler, proved by Galileo, and established by Newton.

Of all the attempts here to find latter-day Copericanism, possibly the most convincing is by Robert L. Sinsheimer, who argues that the overthrow of vitalism—the belief that living matter differs from non-living by the presence of a mysterious power in each fundamental part—was in fact Copernican. He presents the case well, noting that the breakthrough came gradually, even painfully; but once reached, it had profound influence in medicine, psychology, and other fields. But even this signal impact pales beside the monumental revolution attributed to the man from Torun.

One of the most exciting aspects of science is its incompleteness. Would it not, therefore, be the scientist's nirvana to read now the NAS commemorative volume to be published in the year 2473. Of what new revolutions would we read, and would Copernicus still be without peer?

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Ion Beams With Application to Ion Implantation

R. G. Wilson, G. R. Brewer
500 pp. Wiley, New York, 1973. $19.95

If you are planning to install a low energy (10–500 keV) heavy-ion accelerator and are confused by the conflicting claims made for different ion sources and analyzing systems, this book should prove invaluable. The authors have distilled their many years of experience in working with such machines into a helpful guide to the novice. If you are presently working with such machines, the information in this book should allow you to optimize the machine's performance as well as provide many helpful operating hints.

The authors, Robert G. Wilson and George R. Brewer, start with a lengthy description of the mechanisms of producing ions and discuss a whole array of ion sources (such as surface-ionization sources, FR sources, Plasmatrons, oscillating-electron ion sources and others). Their discussions are not limited to a brief description of the sources but include the advantages and shortcomings as well as typical operating parameters and results for each type of source. Many of the graphs for ion-source parameters stem from their own unpublished work. The authors are able to remove the "sorcery" part of "ion sorcery." The discussion of ion-beam extraction and transport system utilizes matrix representation of ion optics. This is a very convenient and powerful method, especially when digital calculating machines are available. Basic ion or electron optics are not treated thoroughly by the authors but an ample bibliography more than makes up for this omission. For beam-analyzing systems the authors recommend a crossed electric and magnetic field velocity selector (Wien filter) and give a good theoretical treatment of this analyzing system. The theoretical results are interwoven with results from actual working systems, and many practical limits are given. The last section of the book, on system-design considerations of ion implantation systems, should prove very helpful for anyone who is presently in the planning stage for such a facility. All chapters have an extensive and adequate bibliography and additional information (vapor pressure of materials, toxicity of gases) that is very helpful in operating ion sources and small accelerators.

When the authors review the basic physics required for ion implantation (including stopping power, range theory, channeling and sputtering) the treatment is very elementary, even misleading in certain instances, and does not approach in rigor or sophistication the description they give of ion sources or beam-transport systems. This is a serious shortcoming of the book, because an intelligent discussion of this subject would be extremely valuable to workers in this field.

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The Intensity Interferometer, Its Application to Astronomy

R. Hanbury Brown
184 pp. Halsted, New York, 1974. $18.75

As dusk falls on the Australian plains, two seven-meter-tall mosaic mirrors move into position on the circumference of a 188-meter-diameter circle and follow a single star across the southern sky. A photomultiplier tube at the focus of each samples an eight-nanometer slice of the star's spectrum and sends a 100-MHz bandwidth signal via a tenth of a kilometer of coaxial cable to a correlator that measures the time average of the product of the signals from the two tubes. Each night, as the mir-