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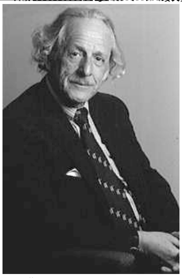

Current Comments®

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The New 1945-1954 *SCI* Cumulation Provides Unique Access to the Crucial Postwar Decade of Scientific and Technological Achievement

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This fall ISI® is publishing the 1945-1954 *Science Citation Index*® cumulation. This index offers unprecedented citation access to the scientific and technical literature of the decade following World War II. This crucial period of scientific discovery and growth continues to influence current research.

In 1983, when I announced the 1955-1964 *Science Citation Index*® (*SCI*®) cumulation, I expressed the hope that the *SCI*'s retrospective coverage of the scientific literature would one day extend back to the turn of this century.[1] That remains our ultimate goal.

In the meantime I am pleased to announce another large step toward the attainment of that goal: the 1945-1954 *SCI* cumulation, to be published this fall. For the first time, an index covering the crucial post-World War II decade that saw important breakthroughs in science and technology will be available. Many of these breakthroughs continue to affect research in such areas as molecular genetics, pharmaceuticals, nuclear medicine, and electronics. In this essay, in addition to highlighting the new *SCI* 1945-1954 cumulation, we'll examine some of the work from that decade and demonstrate its continuing importance.

A Decade Never Before Indexed

The citation data in the *SCI*, 1945-1954, has never before been indexed in the *SCI* and does not appear in any other *SCI* volume—print, online, or compact disk read-only-memory (CD-ROM). The index covers 35,000 issues from nearly 500 journals, resulting in approximately 750,000 source items and 8.2 million citations.

This wealth of literature represents a decade's worth of key advances, breakthroughs, and inventions. The 1953 announcement of the DNA double helix, for example, is only one such achievement. Other scientific and technological advances from this era include the first supersonic flight; the first "electronic brain"; the first solar battery; the invention of the electronic transistor; the first use of nuclear energy to produce municipal electric power; the development of cortisone as a cure for rheumatism; the first nuclear-powered submarine; the synthesis of vitamin A; the development of important antibiotics, such as chlortetracycline; and rapid expansion in the use of radioisotopes in scientific research, medicine, and industry. This is but a sampling of this decade's advances in electronics, aviation, astronomy—not to mention achievements in molecular biology and in recombination and transduction in bacteria.

Science historian Arnold Thackray, University of Pennsylvania, Philadelphia, points out that this era also saw important progress in our understanding of polymers. He notes that although the development of nylon and other synthetic fibers predates this period, this decade was essential in laying out an understanding of polymeric materials and developing practical abilities with them. This era, in effect, set the stage for the building of a world of synthetic polymers and plastics and also opened the way towards an understanding of *biological* polymers.[2]

In the US this was a decade of expanded government support for science. In late 1944, seeking recommendations on how the wartime mobilization of scientific and technical resources could be applied to peacetime goals, President Franklin D. Roosevelt sent a letter to Vannevar Bush, Office of Scientific Research and Development. "New frontiers of the mind are before us," Roosevelt wrote, "and if they are pioneered with the same vision, boldness, and drive with which we have waged this war we can create a fuller and more fruitful employment and a fuller and more fruitful life."[3] (p. viii) Bush's subsequent report, published in 1945 as *Science: The Endless Frontier*,[3] recommended the formation of a federal agency to support and administer scientific education, research, and policy. The result was the National Science Foundation (NSF). NSF historian J. Merton England describes the organization's formative years, 1945 to 1957, in *A Patron for Pure Science*.[4]

Highly Cited Works

Many super-cited papers are from this decade. One, in fact, is "Protein measurement with the Folin phenol reagent," the 1951 paper by Oliver H. Lowry and colleagues, Department of Pharmacology, Washington University School of Medicine, St. Louis, Missouri, which is the all-time citation leader.[5] As we've observed previously, this paper has now been explicitly cited in over 167,000 publications since 1955. However, Lowry also coauthored another super-cited paper from this era. Published in 1946, "A method for the rapid determination of alkaline phosphatase with five cubic millimeters of serum"[6] has been cited over 2,000 times since 1955.

Both of these papers appeared in the *Journal of Biological Chemistry*. In fact, when we used the *SCI*, 1955-1986, to identify the most-cited paper from each year in this decade, we found that 5 of the 10 papers appeared in that journal. We also noted a predominance of methods papers among these 10, as has often been the case in our studies of highly cited papers. When the new 10-year cumulation appears we will be able to tell how quickly these methods became popular.

Recently, we published a two-part essay updating the most-cited papers in the *SCI*, 1955-1986.[7] With that update, we capped a series of essays identifying 1,200 highly cited papers from the *SCI*. Of those papers, approximately 12 percent are from 1945 to 1954. When considering this statistic, of course, one must take into account the relative sizes of the literature then and now. For example, we indexed 750,000 papers for this 10-year period. Currently, the scientific literature for *one* year exceeds that figure.

As mentioned above, we have previously highlighted the works of Lowry and colleagues, as well as many of the other *Citation Classics®* from this decade. Of course, many other papers from this decade could not be included in our series on the top 1,200 papers. Listed in Table 1 are 14 such papers published from 1945 to 1954; all have been cited more than 810 times since 1955. One is by William G. Cochran, Johns Hopkins University, Baltimore, Maryland: "Some methods for strengthening the common χ^2 tests." In this 1954 paper from *Biometrics*, Cochran discusses the χ^2 tests of goodness of fit and of association in contingency—statistical methods commonly used (and misused) in reports of biological research. He offers methods for making the best use of these techniques.

Another paper in Table 1 is "The technique of free skin grafting in mammals," by R.E. Billingham and P.B. Medawar, then of the Department of Zoology, University of Birmingham, UK, which appeared in the *Journal of Experimental Biology* in 1951. The article discusses procedures and principles based on the authors' experiences with skin grafting in rabbits, guinea pigs, and mice. Sir Peter Medawar, along with Sir F. Macfarlane Burnet, received the 1960 Nobel Prize in physiology or medicine for work on acquired immunity in tissue transplants. Medawar, who died recently after a prolonged illness, will also be remembered for his many reflections on the life of a scientist.[8-10] (Later in this essay we'll discuss other Nobel laureates of the decade.) Bil-

Table 1: Highly cited articles published between 1945 and 1954 and cited at least 810 times in the *SCI®*, 1955-1986. Articles that appear in our most-cited *SCI* articles studies for 1961-1982 or 1955-1986 have been excluded. A=total number of citations from the *SCI*, 1955-1986. B=bibliographic information.

A	B
838	**Billingham R E & Medawar P B.** The technique of free skin grafting in mammals. *J. Exp. Biol.* 28:385-402, 1951.
820	**Biozzi G, Benacerraf B & Halpern B N.** Quantitative study of the granulopectic activity of the reticulo-endothelial system. II. *Brit. J. Exp. Pathol.* 34:441-57, 1953.
831	**Bulbring E.** Observations on the isolated phrenic nerve diaphragm preparation of the rat. *Brit. J. Pharmacol.* 1:38-61, 1946.
839	**Cochran W G.** Some methods for strengthening the common χ^2 tests. *Biometrics* 10:417-51, 1954.
818	**Harvey A E & Manning D L.** Spectrophotometric methods of establishing empirical formulas of colored complexes in solution. *J. Amer. Chem. Soc.* 72:4488-93, 1950.
811	**Herring C.** Diffusional viscosity of a polycrystalline solid. *J. Appl. Phys.* 21:437-45, 1950.
844	**Kalckar H M.** Differential spectrophotometry of purine compounds by means of specific enzymes. I. Determination of hydroxypurine compounds. *J. Biol. Chem.* 167:429-43, 1947.
814	**King E O, Ward M K & Raney D E.** Two simple media for the demonstration of pyocyanin and fluorescin. *J. Lab. Clin. Med.* 44:301-7, 1954.
811	**McManus J F A.** Histological demonstration of mucin after periodic acid. *Nature* 158:202, 1946.
827	**Ramsay D A.** Intensities and shapes of infrared absorption bands of substances in the liquid phase. *J. Amer. Chem. Soc.* 74:72-80, 1952.
840	**Rice S O.** Mathematical analysis of random noise. Part III. Statistical properties of random noise currents. *Bell Syst. Tech. J.* 24:46-158, 1945.
810	**Steinbrocker O, Traeger C H & Batterman R C.** Therapeutic criteria in rheumatoid arthritis. *J. Amer. Med. Assn.* 140:659-62, 1949.
812	**Toennies G & Kolb J J.** Techniques and reagents for paper chromatography. *Anal. Chem.* 23:823-6, 1951.
833	**Wang M C & Uhlenbeck G E.** On the theory of Brownian motion II. *Rev. Mod. Phys.* 17:323-42, 1945.

lingham is now affiliated with the Department of Cell Biology, University of Texas Health Science Center, Dallas.

Citation Classics

More than 250 *Citation Classic* commentaries on work done during this era have been published in *Current Contents®* (*CC®*). (Those published in *CC* by 1984 have been collected in the ISI Press® series called Contemporary Classics in Science.) It is impossible, given this limited space, to do justice to the breadth of research contained in these *Classic* papers. However, a brief sampling does convey something of the diversity of the *Classic* commentaries on work from this era. Gerhard Herzberg, National Research Council of Canada, Ottawa, Ontario, for example, commented in 1983 on his book *Molecular Spectra and Molecular Structure. I. Spectra of Diatomic Molecules.*[11] This book, originally published in 1939, has been cited in over 7,900 publications since 1955. A second volume, *Molecular Spectra and Molecular Structure. II. Infrared and Raman Spectra of Polyatomic Molecules*,[12] first appearing in 1945, has been cited nearly 2,500 times since 1955.

A 1952 paper from the *Journal of Biological Chemistry* by L.L. Abell and colleagues, Columbia Research Service, Goldwater Memorial Hospital, Roosevelt Island, New York, was the subject of a 1979 commentary. The paper describes a method for determining total cholesterol in serum. According to Abell, the method had its origin in the late 1940s, when cholesterol was first implicated as a cause of arteriosclerosis. Determining serum cholesterol levels was a laborious and time-consuming process, and Abell and his colleagues sought a shorter method that would still be accurate and reliable. Their procedure, as Abell noted, is still used as a standard method in many laboratories around the world.[13] This paper has been cited over 2,700 times since 1955.

A 1946 paper on radio astronomy, "The measurement of thermal radiation at microwave frequencies," by R.H. Dicke, Massachusetts Institute of Technology, Cambridge, was the subject of a 1980 commentary. Dicke noted that "serendipity" played a substantial role in the invention of his radiometer:

> It suddenly occurred to me one day in 1944 that the performance of a standard

microwave radar receiver as a detector of incoherent thermal radiation was extremely poor at centimeter wavelengths and that it could be vastly improved by rapidly switching the receiver input back and forth between the antenna and a dummy antenna, a second source of thermal radiation.[14]

Dicke and his colleagues used the radiometer in 1945 to measure radiation emitted by the most distant known galaxies in the universe. Subsequently, some 20 years later, Dicke and his colleagues built a radiometer to measure the microwave background radiation that would support the "big bang" theory. Before this radiometer was completed, however, Arno A. Penzias and Robert W. Wilson, Bell Laboratories, Holmdel, New Jersey, "accidentally" found this form of radiation,[15] a discovery that won them the 1978 Nobel Prize in physics.

According to Helmut A. Abt, Kitt Peak National Observatory, Tucson, Arizona, this postwar decade was the era in which radio astronomy began. Although Karl G. Jansky, Bell Telephone Laboratories, New York, and radio engineer Grote Reber discovered radio radiation from the Milky Way and the sun before World War II, it was the development of radar and the much-improved sensitivity of large radio receivers that allowed the detection of the extremely faint radio noise from planets, galaxies, and interstellar gas.[16] (Jansky's key paper[17] was discussed by J.S. Hey, Eastbourne, UK, in a *Citation Classic* commentary published in 1984.[18]) This opened up a new field that jumped from less than 1 paper per year before World War II to about 100 papers per year by 1954. It was a surprise to scientists that the most intense radio radiation came not from visibly obvious objects, such as stars and nebulae, but from nearly invisible objects, such as the radio lobes of galaxies, quasars, and the microwave background radiation.[16]

Research Fronts

One measure of the continuing influence of research from this decade can be found in 1986 and 1987 ISI® research fronts. These fronts are formed when contemporary authors collectively cite a group of previous papers. These cited papers form the core of the research front. In Table 2 we present a list of fronts having at least one core publication from 1945 to 1954. For example, *Theory of X-Ray Diffraction in Crystals*, a 1945 book by William H. Zachariasen, University of Chicago, Illinois,[19] is 1 of 52 core works in "X-ray and neutron powder diffraction data, refinements and structures of graphite intercalation, and other compounds" (#87-0572). The 427 current citing

Table 2: Selected 1986 and 1987 C1-level research fronts with at least one core document from 1945 to 1954. A = number of core papers. B = number of citing papers. The core items that appear in the research front are given after the research-front name.

Number	Name	A	B
86-2707	Stage transformation in graphite-intercalation compounds Jagodzinski H. *Acta Crystallogr.* 2:201-7, 1949. Kakinoki J & Komura Y. *J. Phys. Soc. Jpn.* 7:30-5, 1952.	22	144
87-0129	Verrucous carcinoma and Bowen's disease Ackerman L V. *Surgery* 23:670-8, 1948.	2	17
87-0572	X-ray and neutron powder diffraction data, refinements and structures of graphite intercalation, and other compounds Zachariasen W H. *Theory of x-ray diffraction in crystals*, 1945.	52	427
87-0778	Fluorescence quenching reactions, relaxation kinetics, and NA^+-induced conformational change of the intestinal brush-border sodium glucose symporter Collins F C. *J. Colloid Sci.* 4:425-37, 1949.	16	261
87-1131	Trends in proportions Armitage P. *Biometrics* 11:375-86, 1955. Cochran W G. *Biometrics* 10:417-51, 1954.	2	65
87-1146	Effects of exercise, particularly jumping, on muscle activity Bigland B & Lippold O C J. *J. Physiol.—London* 123:214-24, 1954. Lippold O C J. *J. Physiol.—London* 117:492-9, 1952.	10	74
87-4989	Genetic differentiation and evolutionary classification in plants and animals Dobzhansky T. *Genetics and the origin of species*, 1951.	4	125

papers in this front indicate considerable contemporary research activity in this area, which deals with solid-state chemistry. And, more than 30 years after its publication, the Zachariasen book continues to be acknowledged by citing authors as a key contribution.

Highly Cited Postwar Books

Similarly, a 1951 book, *Genetics and the Origin of Species*, by the late Theodosius Dobzhansky, Columbia University, New York,[20] is one of four core documents in a 1987 front on "Genetic differentiation and evolutionary classification in plants and animals" (#87-4989). There were 125 papers published in this area last year. Dobzhansky's book has received approximately 900 citations since 1955.

One might expect that most technical books published over 35 years ago would be out of print. But, as our data show, many highly cited books produced in this decade are still in print. One example is *Molecular Theory of Gases and Liquids*, by Joseph O. Hirschfelder, Charles F. Curtiss, and R. Byron Bird, University of Wisconsin, Madison.[21] This 1954 book has been cited over 6,800 times since 1955. Another book from 1954, *Dynamical Theory of Crystal Lattices*, by Max Born, University of Edinburgh, UK, and Kun Huang, University of Peking, People's Republic of China,[22] has been cited over 3,200 times since 1955.

Journals

During this postwar decade, the size of the journal literature grew considerably. According to *Ulrich's International Periodicals Directory*, more than 9,700 "serials" worldwide, representing all subjects, began publication in the years 1945-1954. This is nearly as many as the 10,300 journals that were started between 1900 and 1945. Derek John de Solla Price, in *Little Science, Big Science*, remarks on the postwar growth of the scientific literature.[23]

Of the journals that appeared between 1945 and 1954, approximately 2,290 new journals were started in the US, 1,280 in Germany, 660 in the UK, 640 in France, and 635 in Italy. These five countries, in fact, account for more than 55 percent of these journals. Twenty countries account for over 90 percent. Of the journals that began during this decade, nearly 30 percent were scientific or technical in nature.

Only about 12 percent of the journals begun between 1945 and 1954 have ceased publication. Currently, there are 233 journals indexed in the *SCI* that began publication during the decade 1945-1954. Among the journals that started at this time, and that continue to thrive, are many review journals, including several editions in the *Annual Reviews* and *Advances in* series. Table 3 is a list of high-impact journals that began publication during this decade, including *Advances in Cancer Research*, the *Annual Review of Physical Chemistry*, and the *American Journal of Medicine*. In addition to the journals in Table 3, other notable journals that began include: *Acta Crystallographica. Section A. Foundations of Crystallography*; *BioScience*; *Evolution*; and several sections of the *IEEE Transactions* (the Institute of Electrical and Electronics Engineers [IEEE] was formerly known as the Institute of Radio Engineers).

Table 3: High-impact journals that began publication between 1945 and 1954 and are indexed in the 1988 *SCI*®. A=1986 *JCR*® impact factor. B=number of papers cited 50 or more times in the *SCI*, 1955-1986. C=journal title and first year of publication.

A	B	C
7.14	128	Advan. Cancer Res. (1953)
3.20	102	Advan. Catal. (1948)
7.00	183	Advan. Phys. (1952)
5.47	238	Amer. J. Hum. Genet. (1949)
3.21	1,896	Amer. J. Med. (1946)
3.60	97	Annu. Rev. Med. (1950)
4.94	224	Annu. Rev. Microbiol. (1947)
3.56	92	Annu. Rev. Nucl. Par. Sci. (1951)
7.16	122	Annu. Rev. Phys. Chem. (1950)
13.40	326	Annu. Rev. Plant Physiol. (1950)
5.07	26	Annu. Rev. Psychol. (1950)
5.59	220	Astrophys. J. Suppl. Ser. (1954)
6.22	1,369	Blood (1946)
3.98	927	Brit. J. Pharmacol. (1946)
7.54	2,469	Circulation (1950)
5.72	1,665	Circulation Res. (1953)
4.39	644	Diabetes—US (1952)
3.02	516	Geochim. Cosmochim. Acta (1950)
4.61	252	Int. Rev. Cytol. (1952)
4.01	613	J. Histochem. Cytochem. (1953)

Nobel Laureates

A further measure of the value of the research from this decade is provided by the number of Nobel Prize winners who were active then.

One such Nobel laureate, of course, is Joshua Lederberg, president, The Rockefeller University, New York. Recently, we reprinted Lederberg's own account, from the *Annual Review of Genetics*,[24] of his research in genetic recombination in bacteria.[25] For this research, initially published in 1946, Lederberg shared the 1958 Nobel Prize in physiology or medicine with Edward L. Tatum, The Rockefeller Institute for Medical Research, New York, and George W. Beadle, California Institute of Technology, Pasadena.

In addition to Lederberg, many scientists were involved between 1945 and 1954 in research that would result in Nobel Prizes. In Table 4 we list 32 Nobel laureates who, during this decade, performed the major part of the work recognized by the Nobel committees (the table includes the year they actually won the award). We identified five Nobel Prize winners who performed their key research *and* received the Nobel between 1945 and 1954: Edward M. Purcell (physics, 1952), honored for developing magnetic measurement methods for atomic nuclei; Fritz A. Lipmann (physiology or medicine, 1953), who won for discoveries in biosynthesis and metabolism; and John F. Enders, Frederick C. Robbins, and Thomas H. Weller (physiology or medicine, 1954), who discovered a method for growing polio virus in test tubes.

Patent Searching

The first years of the postwar decade brought the beginning of a patent citation system to US patents. Thus, for the first time since the creation of the US Patent Office in 1836, patents listed on the printed patent itself the references cited against certain claims in the patent application that eventually issued as the patent. As I noted in a 1957 paper in the *Journal of the Patent Office Society*, these references have been included with all patents published since February 4, 1947.[26] This, in essence, amounted to a bibliography of the relevant prior art and would enable any reader of the patent to determine the prior art that had been considered by the patent examiner. This information had previously been included only in the "wrapper"—that is, the application file folder stored at the Patent Office.

Recognizing the potential value of these references, Arthur H. Seidel, then at Gulf Oil Company, Washington, DC, wrote a letter published in the July 1949 issue of the *Journal of the Patent Office Society*.[27] This primordial suggestion for a patent "citator"—that is, a citation index—had significant consequences in the development of the *SCI*. Indeed, by a fortuitous set of circumstances, Arthur and I met after we had corresponded. He came to Philadelphia to practice patent law and I came to practice information science. The complete story will be told later in an essay devoted to patents, but in the meantime it is important to point out that the *SCI* has always contained its own Patent Citation Index—that is, citations to patents from journal articles.

The mix of technology covered by US patents has undergone a tremendous change since the 1945-1954 decade. It has been estimated that at the beginning of that decade more than 60 percent of the issued patents related to mechanical devices, with the remainder about evenly split between electrical and chemical inventions. Thus, as Seidel notes, in the early postwar years far more than half of the practicing patent attorneys were mechanical engineers by training.[28]

A count of the 1,495 US patents issued during the week of March 29, 1988, revealed that 43 percent were mechanical, 30 percent were chemical, and 27 percent were electrical. Furthermore, because of the relative complexity of the chemical and electrical technology, a small minority of the patent attorneys entering the profession today have mechanical engineering backgrounds—the great bulk of them having backgrounds in chemistry or chemical engineering, electrical or industrial engineering, physics, and computer science. And, of course, in recent years the growth of bio-

Table 4: Nobel Prize winners who received the prize for a span of work that began and ended in 1945-1954. A=starting year of the span of work for which the prize was awarded. B=last year of the span of work for which the prize was awarded. C=year of prize and category. D=Nobel Prize winner. Asterisks (*) indicate span of work began, ended, and prize won between 1945 and 1954.

A	B	C	D
1945	1949	1955, Physics	Willis E. Lamb
1945	1945	1953, Physiology/Medicine	*Fritz A. Lipmann
1945	1953	1960, Physiology/Medicine	Sir Peter B. Medawar
1946	1948	1952, Physics	*Edward M. Purcell
1946	1948	1956, Physics	John Bardeen
1946	1948	1956, Physics	Walter Brattain
1946	1948	1956, Physics	William Shockley
1946	1952	1954, Physiology/Medicine	*John F. Enders
1946	1953	1958, Physiology/Medicine	Joshua Lederberg
1946	1953	1962, Physiology/Medicine	Maurice H.F. Wilkins
1947	1948	1955, Physics	Polykarp Kusch
1947	1952	1954, Physiology/Medicine	*Thomas H. Weller
1947	1952	1960, Chemistry	Willard F. Libby
1947	1954	1967, Chemistry	R.G.W. Norrish
1947	1954	1967, Chemistry	Sir George Porter
1948	1948	1963, Physics	J. Hans D. Jensen
1948	1949	1963, Physics	Maria Goeppert-Mayer
1948	1951	1971, Physics	Dennis Gabor
1948	1952	1954, Physiology/Medicine	*Frederick C. Robbins
1949	1950	1975, Physics	James Rainwater
1949	1950	1969, Chemistry	Sir Derek H.R. Barton
1949	1949	1960, Physiology/Medicine	Sir F. Macfarlane Burnet
1950	1953	1975, Physics	Aage Bohr
1950	1951	1965, Physiology/Medicine	Andre Lwoff
1951	1953	1962, Physiology/Medicine	Francis H.C. Crick
1951	1953	1962, Physiology/Medicine	James D. Watson
1952	1952	1960, Physics	Donald A. Glaser
1952	1953	1975, Physics	Ben Mottelson
1952	1952	1981, Chemistry	Kenichi Fukui
1952	1953	1963, Physiology/Medicine	Sir John C. Eccles
1952	1952	1969, Physiology/Medicine	Alfred D. Hershey
1953	1954	1963, Chemistry	Karl Ziegler

technology patents has been significant. Will the new generation of patent attorneys be ex-molecular biologists?

The Value of a Retrospective Cumulation

Our previous *SCI* cumulations have proved to be valuable reference tools. As our library users have informed us, the cumulations can save considerable time and effort, particularly in tracking down and verifying references to older papers. The cumulations provide concise, highly useful summaries of authors' publication and citation records in one multidisciplinary index.

With the 1945-1954 *SCI* cumulation, this utility and convenience extend back a further decade, and beyond. Remember that there is no chronological limit to what may be cited and included in the *SCI*. I often wonder to what extent the review literature of this decade adequately covered the previous decade, including the war years. Once we have done a co-citation clustering of this file, we can begin to answer this question. The resulting inventory of research fronts for that period will enable us to identify *Citation Classics* regardless of journal rank.

This cumulation, of course, provides more than convenience. Like its predecessors, it offers unique access to the history of science. Science historians, or anyone interested in tracking the genesis and development of a theory, a discovery, or a general area of research, will find the new cumulation to be an indispensable resource.

* * * * *

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