the 80-column IBM card. The number of possible codes is $400!/4!396! \doteqdot 10^9$.

A 20,000-card deck of master cards was prepared, by machine methods, from the first 5000 cards of a random-digit deck obtained from the Rand Corporation. Each Rand card contains 50 random digits. The first 48 digits were divided into four equal groups; each such group was used to produce a four-hole pattern. For this purpose the group of 12 digits was subdivided into four three-digit numbers, and each of these was interpreted as a hole. Each three-digit number not already in the range 000–399 was converted to one in that range; then the number 238, for instance, was interpreted as "punch 8 in column 23" (card column 40 was renamed 00).

To preserve the randomness, the conversion was done as follows. Initial 4, 5, 6, 7 were replaced by 0, 1, 2, 3, respectively; initial 8 by 0 or 1; initial 9 by 2 or 3. The approximately 8000 choices between 0 and 1 were made at random, by use of the 5000 random digits in column 49 of the Rand cards; the choices between 2 and 3 were made by use of column 50. The first 5000 of the 8000 choices were determined by whether a digit was in the set 0, 1, 2, 3, 4 or in the set 5, 6, 7, 8, 9. The remaining choices were determined by whether a digit was in the set 0, 1, 8, 9 or in the set 3, 4, 5, 6; digits 2 and 7 were rejected.

The abstract cards are produced as follows. A scientist reads the printed abstract and lists the attributes to be coded: for example, *solution, compressibility, sodium, chloride*. These are taken from a standard list or, when necessary, added to it. A machine operator does the rest. Each attribute on the list has a serial number, which is also punched on the corresponding master card. Master cards with the specified serial numbers are selected by machine methods. For each abstract, the codes are reproduced first from the master cards to separate detail cards, then from each detail card to the next, until finally a single card contains the superposed codes for all the attributes.

A search can be made as follows. When n attributes have been specified, the corresponding pattern of holes ($4n$ or fewer) is determined. The entire file is put through the sorter once, to select cards punched with a specified hole. The selected cards (a small fraction of the total) are put through again, to select cards punched with a second specified hole; and so on. A search can be made with a *single* pass through a more elaborate machine; but the sorter is fast and inexpensive.

To test the coding and search procedures, about 2500 abstracts, published by the American Petroleum Institute, were indexed; 377 of these were converted into abstract cards (*4*); 1700 attributes were needed. The coding and punching were done twice, independently, and the cards were compared in the reproducer. When two persons with different backgrounds (chemistry and physics) indexed independently and then compared, abstracts were converted to cards at the rate of 2.3 per man-hour. When only one person indexed, the rate was 3.0 per man-hour. One-word attributes worked well. The work of coding and punching additional attributes was outweighed by the flexibility gained in indexing; new concepts could be indexed more precisely.

Several trial searches were made with the 377 cards. No difficulties emerged, and in one search an abstract was found that had been missed in the conventional search. The file was too small to permit reliable estimation of searching time.

WILLIAM FULLER BROWN, JR.*
GLEN ONEAL, JR.†
Sun Oil Company, Physical Laboratory, Newtown Square, Pennsylvania

References and Notes

1. W. W. Stifler, Jr., Ed., *High-Speed Computing Devices* (McGraw-Hill, New York, 1950), Chap. 9.
2. S. V. Larkey, *Bull. Medical Library Assoc.* 41, 32 (1953).
3. R. S. Casey and J. W. Perry, Eds., *Punched Cards and Their Applications to Science and Industry* (Reinhold, New York, 1951).
4. We gratefully acknowledge the valuable assistance of Kate C. Ornsen, Margaret Johnson, and Carl W. Dempsey.

* Present address: Central Research Department, Minnesota Mining and Manufacturing Company, St. Paul 6, Minn.
† Present address: Research and Development Department, American Viscose Corporation, Marcus Hook, Pa.

9 January 1956

Dangerous Dagger

Lately this laboratory received from abroad a note of commiseration on the sudden death of our distinguished director, who, happily, is much alive. Misunderstanding apparently arose from the heading of a published paper, where the author's name was followed by a dagger (†).

On the continent of Europe the dagger thus placed is almost universally understood to indicate posthumous publication. However, many American editors use it for a footnote giving the author's professional connection or other information. This happens commonly when an asterisk follows the title. Would it be too revolutionary to replace the dagger by some other symbol or a double asterisk?

CHARLES F. RICHTER
Seismological Laboratory, Pasadena, California

6 January 1956

Subject Indexing in a Restricted Field

Uriel H. Schoenbach's letter on "Citation indexes for science" [*Science* **123**, 61 (1956)] contains one of the best solutions to the serious problem of assuring efficient information retrieval from the scientific literature. His suggestion that existing indexing techniques be greatly expanded in order to cover all of the significant aspects of scientific publications, instead of stressing only the "highlights," is certainly very well taken and, if implemented, would greatly facilitate the more efficient communication of data.

The Chemical-Biological Coordination Center of the National Academy of Sciences–National Research Council collects, abstracts, and codes information concerning the effects of chemical compounds upon biological systems (*1*). These data are processed, stored, and retrieved by the use of machine-sorted punch cards. Publications to be abstracted and coded are carefully examined by highly qualified scientists and subjected to the sort of detailed and discriminating indexing that Schoenbach has in mind (*2*). As a result, there may be as many as 20 separate approaches (index entries) to a particular paper (*3*).

Recently, a Cardiovascular Literature Project was set up at the CBCC, supported by research grant H-2045 of the National Heart Institute, National Institutes of Health, U.S. Public Health Service. One of the aims of this group is to collect, index, and publish all the available information in the world literature concerning the effects of chemical agents upon the cardiovascular system.

The Current List of Medical Literature of the Armed Forces Medical Library performs an excellent and indispensable service not only to the medical community but to documentation as a whole. The indexing and publication techniques employed in the present undertaking are based largely on similar methods that have been evolved and successfully used by the Current List. As a result of the restricted subject matter encompassed by the project, a much more detailed type of indexing can be employed. It is estimated that the "average" publication thus far examined by us contains about ten index entries (*4*).

All chemical compounds tested for any cardiovascular effect are separate index subject headings (generic names and *Chemical Abstracts* names are used). For biological entities, a list of specific subject headings, with ample cross-references, similar to that compiled by the Current List (*5*), but in greater detail, is used.

The published multi-indexed bibliography will appear as a series of separate volumes, each covering a specific chronological period. It is planned that the first of these will encompass the world literature from 1951 to 1955, inclusive. The success of this undertaking should provide practical confirmation of the validity of Schoenbach's observations. Other alternatives exist, but it is difficult to find a better practical solution to the problems of adequate bibliographic control at the present stage of development of documentation research.

ISAAC D. WELT
Cardiovascular Literature Project, Chemical-Biological Coordination Center, National Academy of Sciences–National Research Council, Washington, D.C.

References

1. The Chemical-Biological Coordination Center, National Academy of Sciences–National Research Council, 33 pp. (1954).
2. R. L. Beard and K. F. Heumann, *Science* 116, 553 (1952).
3. G. C. Wood, *Special Libraries* 47, 26 (1956).
4. I. D. Welt, "Indexing of chemical-biological data in a restricted field of medical science," unpublished (1955).
5. Subject Heading Authority List used by the Current List Division, Armed Forces Medical Library (1954).

6 March 1956

Age and Productivity among Scientists

This paper is concerned with the output of scientific papers among a group of scientists all of whom reached the age 70 and many of whom lived to age 80 or beyond. Among the topics examined are the following: What is the relative productivity of a scientist at various decades of life? What percentage of his total bibliography is produced by age 30, age 40, and so forth? How many contributions are made during the additional decade that is allotted to the octogenarians?

Because my bibliographic source provided data only for the 19th century, it was necessary to choose for study scientists whose adulthood fell entirely between 1800 and 1900. In order to obtain subjects, I selected from the biographical directory of *Webster's New International Encyclopedia,* 1930 edition, each scientist listed therein who lived to age 70 or beyond and whose years of life from age 20 onward fell between 1800 and 1900. This procedure yielded the names of 156 scientists. Of these, 100 lived to ages 70 to 79, inclusive, while 56 lived to ages 80 to 89. The few who survived to age 90 or beyond are not treated in this report.

The 156 subjects belonged to a variety of scientific specialties. There were 17 astronomers, 24 chemists, 19 geologists, 17 mathematicians, 34 naturalists, 15 physiologists, and 20 physicists, while 10 fell into other categories or were difficult to classify. In general they were eminent men in their respective fields, and many are universally famous.

For each subject, a count was made of the number of his scientific publications per decade of life as listed in the *Catalog of Scientific Literature, 1800–1900,* prepared by the Royal Society of London. This catalog lists only papers published in scientific journals and in the proceedings of scientific societies. It does not list other publications, such as books, letters to editors, memorial addresses, obituaries, popular writings, and so on. Thus we are not dealing with complete bibliographies but only with scientific periodical literature. It is believed, however, that the major part of the bibliography of science consists of this kind of publication.

For convenience, the group living to ages 70 to 79 is called the 70-year group, and the remainder is called the 80-year group.

Table 1 shows the mean number of papers published per man, per decade, for each group and for the combined groups. This table indicates that productivity between ages 20 and 29 is quite low. The low productivity of this decade is the result, in large part, of the very low productivity between ages 20 and 24. Of the 156 subjects, 96 did not begin to publish until age 25 or later. However, even the second half of the decade of the 20's does not equal the record of later productivity.

In the 30's a high average rate of productivity is reached, and this rate is maintained for three decades. On the whole, there is little change in mean output of scientific articles between age 30 and age 59. The mean output of my subjects during this period approximates two publications per year. The rate of publication for the combined groups decreases about 20 percent in the 60's, and the 80-year group shows a still further decline in the 70's, although an appreciable amount of productivity is maintained. It will be noted that the number of publications appearing in the 70's is considerably higher than the number in the 20's.

Although the statements just made indicate the general trends, there are, of course, individual exceptions to these. The range of productivity, within each decade, and over the total life span, is great, even for this group of highly eminent men. The distributions are skewed to the left, resembling the upper end of a normal distribution curve. Because of the nature of the distributions, the usual measures of variability are not appropriate and, hence, are not presented.

Next, my data are treated so as to show the proportion of the eventual bibliography that is produced by the close of each decade. In the figures that follow, it should be noted that the bibliographies of the 70-year group were closed at age 70 and those of the 80-year group at age 80, as in Table 1. However, the percentages obtained would be only slightly altered if we based them on bibliographies at death rather than at ages 70 and 80. The results obtained are shown in Table 2. It will be observed that a very small part of the lifework of these men was completed by age 30. About one-third of their publications had appeared by age 40. It is notable that nearly one-half of their output appeared after age 50.

Between ages 20 and 70 members of the 70-year group produced a mean of 92.8 papers each. Between ages 20 and 80 the 80-year group published a mean of 102.2 papers per person. This comparison suggests that, for a man of the calibre with which we are dealing, an additional decade of life beyond age 70 results in the production of approximately 10 scientific papers.

Another way to examine this problem is to compare the record of the 80-year group at age 70 with its own record at age 80. Between age 70 and age 80, the mean bibliography of the 80-year group increased from 89.1 to 102.2, a gain of 13.1 papers.

In an earlier paper (*1*), correlations between the degrees of productivity in different decades were computed for two groups of scientists living to age 70. The

Table 1. Mean number of papers per person per decade.

Decade	20's	30's	40's	50's	60's	70's
70-year group	9.1	20.1	21.8	23.8	18.1	
80-year group	6.9	21.9	24.7	18.5	17.0	13.1
Combined groups	8.1	20.7	22.9	21.9	17.7	

Table 2. Percentage of total output completed by various ages.

Age	30	40	50	60	70	80
70-year group	10	32	56	80	100	
80-year group	7	28	52	70	87	100

Table 3. Correlations between degrees of productivity of 56 octogenarians.

Age in decades	Age in decades				
	30's	40's	50's	60's	70's
20's	.57	.46	.46	.35	.33
30's		.49	.50	.47	.55
40's			.80	.75	.62
50's				.65	.61
60's					.84