raphy 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.

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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.

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	

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.

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

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 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

same methods have been applied to the 56 octogenarians of the present group with the results shown in Table 3.

The figures are in substantial agreement with those published earlier. The number of scientific publications in the 70's is closely related to productivity in the 60's. The data show also appreciable relationships between the 70's and decades prior to the 60's, the correlations becoming smaller as the decades are farther removed from the final decade.

Readers who are familiar with the various works of Lehman, recently assembled in a single volume (*2*), will note that my findings are at variance with the general tenor of Lehman's results. However, my findings do not necessarily contradict Lehman's. I have dealt with the total output of scientific articles, whereas most of Lehman's attention has been given to "significant" works. In the instances in which Lehman has analyzed the total output of scientists, each of whom lived to a specified age, he, too, finds that productivity persists in the later decades of life.

Finally, it should be noted that the data here presented on eminent 19th-century scientists are in agreement with those that I have previously presented for members of the National Academy of Sciences and for unselected American psychologists (*1*).

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18 November 1955

High-School Students as Laboratory Assistants

In a recent letter [Science **123**, 185 (3 Feb. 1956)] James G. Busse pointed out the advantages of giving summer jobs in laboratories to promising high-school students. A program of this kind was carried out successfully in the summer of 1955 at the University of California, Berkeley, in the departments of biochemistry and physiological chemistry. Results were very encouraging in that students and employers were well satisfied. The students were enthusiastic, hard-working, and intelligent laboratory assistants—well worth the time and cost of training. I hope that scientists in other parts of the country will give a trial to hiring high-school students for the summer.

Currently there is a stress on training more scientists (and engineers). The problem actually is to attract able people and not simply to produce more scientists. I believe the latter aim is wrong, because scientists cannot be mass-produced any more than can competent musicians or athletes. There is danger that if we strive simply for quantity of scientists, the level at which science must be taught will be lowered to a point where the education of the truly promising students will suffer. Effective progress in science must be based on good training; and an opportunity for laboratory experience (to demonstrate the actual nature of science) early in the young scientist's career seems to me one of the best ways of commencing his education and of attracting him into science.

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9 March 1956

Verifying Useless Knowledge

As a collector of useless knowledge, I was entranced by the title of the editorial in *Science* for 2 Mar. but was distressed to see Ben Franklin's devastating remark to the Practical Man attributed to Faraday. Lest noncollectors of useless information be misled by Stanley's lapse, let us check our sources and references. Perhaps Faraday *did* say: "Of what use is a newborn baby?" If so, he stole it from Ben without giving him credit, a very un-Faraday-like act.

James Parton in *The Life and Times of Benjamin Franklin* (vol. 2, pp. 514–515) quotes a brief exchange between a practical-minded spectator and Ben. The time was 21 Nov. 1783. Two Frenchmen, Pilatre de Rozier and the Marquis d'Arlandes, had just taken off from the Tuileries in the first free-balloon flight in history. Says the practical defender of "contract" and "project" research: "What is the use of this new invention?" Answers Ben: "What is the use of a newborn child?"

In the *Harvard Classics,* Emerson writes: (*English Traits, Aristocracy,* page 425) "Loyalty is in the English a sub-religion. They wear the laws as ornaments. . . . The economist of 1855 who asks, of what use are the lords? may learn of Franklin to ask, of what use is a baby?"

Of what use is useless knowledge? has ever been the province of semantics, epistemology—and basic inquiry in anything for the Shopes, the Flemings, the Roentgens, and the fathers and mothers of all newborn babes.

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9 March 1956

Committee on Mathematical Biology

We are disturbed by the drastic reductions that have been imposed on the Committee on Mathematical Biology, headed by N. Rashevsky at the University of Chicago. We wish to point out that the work of this department, the only one of its kind in the world, is of great interest and importance in our diverse fields of research, that is, in biology, clinical medicine, mathematics, psychology, philosophy, and sociology. We feel that it would be a loss if that work were seriously reduced.

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5 July 1955

To write well, even to write clearly, is a woundy business, long to learn, hard to learn, and no gift of the angels.—JOHN GALSWORTHY, Foreword to Hudson's *Green Mansions.*