SCIENCE

VOL. 98 FRIDAY, NOVEMBER 5, 1943 NO. 2549

Man's Most Creative Years: Then and Now: PROFESSOR HARVEY C. LEHMAN 393

Obituary:
William Fogg Osgood: PROFESSORS JULIAN L. COOLIDGE, GEORGE D. BIRKHOFF and EDWIN C. KEMBLE. *Deaths and Memorials* 399

Scientific Events:
The Fortieth Anniversary of the Flight of a Heavier-Than-Air Machine; Preference Ratings for Laboratory Equipment; A Survey of Medical Colleges; Personnel Problems in Geology; Tercentenary Commemoration of the Invention of the Barometer, 1643–1943; American-Soviet Conference; The Tenth Anniversary of the Planetarium and Museum of the Franklin Institute 400

Scientific Notes and News 404

Discussion:
The Botanical Name of the Giant Sequoia: DR. G. NEVILLE JONES. *Apparent Time Acceleration with Age:* PROFESSOR A. J. CARLSON, DR. CYRIL E. ABBOTT and R. P. HARRISS 406

Scientific Books:
Legendre Associated Functions: PROFESSOR R. C. ARCHIBALD. *Man and His Physical Universe:* PROFESSOR S. A. KORFF 409

Special Articles:
Perfusion of Rat Livers with Estrogen in Vitro: JOSEPH SCHILLER and PROFESSOR GREGORY PINCUS. *Inability to Pass Primary Atypical Pneumonia to Human Volunteers:* COMMANDER DEANE H. VANCE, LIEUTENANT THORNTON SCOTT and PROFESSOR HERMAN C. MASON 410

Scientific Apparatus and Laboratory Methods:
Sterility Test for Penicillin: DR. C. A. LAWRENCE. *Quieting Paramecium for the Elementary Student:* DR. DOUGLAS A. MARSLAND 413

Science News 10

SCIENCE: A Weekly Journal devoted to the Advancement of Science, edited by J. MCKEEN CATTELL; WARE CATTELL, assistant editor. Published every Friday by

THE SCIENCE PRESS

Lancaster, Pennsylvania

Annual Subscription, $6.00 Single Copies, 15 Cts.

SCIENCE is the official organ of the American Association for the Advancement of Science. Information regarding membership in the Association may be secured from the office of the permanent secretary in the Smithsonian Institution Building, Washington, D. C.

MAN'S MOST CREATIVE YEARS: THEN AND NOW

By Professor **HARVEY C. LEHMAN**

OHIO UNIVERSITY

IN previous articles the present writer has presented age-curves which set forth the chronological ages at which world-famous geniuses have either achieved or first published their best work.[1] The present study is an attempt to discover whether or not the age-curves thus far obtained are destined to hold for future as well as for past centuries. Although one can not be entirely certain as to what will happen in the centuries that lie ahead, it seems quite possible that a review of what has occurred in the past may provide one with a preview of what is likely to occur in the immediate future.

As a means of investigating the age-changes that may already have taken place the writer has partitioned some of his data upon the basis of the periods during which the various types of creative thinkers were born. In partitioning the data thus it was assumed that, if any change has already occurred in the chronological ages at which eminent thinkers have accomplished the various things which enabled them to attain recognition, this change would perhaps be revealed by study of the partitioned data.

For example, W. F. Magie's "A Source Book in Physics"[2] sets forth the chronological ages at which 140 notable contributions to the science of physics were either made or first published by 89 deceased individuals. In Fig. 1 the broken line sets forth the average number of contributions per ten-year interval for approximately the 50 per cent. that were earliest born, and the solid line sets forth similar information for the 50 per cent. that were most recently born. In both of these age-curves the average number of con-

[1] H. C. Lehman and W. S. Gamertsfelder, *Psychological Review*, 1942, 49; 319–344. (A bibliography of 9 articles of this series is to be found on page 343. In this list the 11th reference should be to the *Psychological Review* instead of to the *Psychological Bulletin.*

[2] W. F. Magie, "A Source Book in Physics." New York: McGraw-Hill Book Co., Inc., 1935. Pp. xiv–620.

tributions per ten-year interval was plotted in order to make proper allowance for the larger number of youthful research workers.

If, regardless of the number of workers that remained alive, the older age groups had contributed at the same average rate as did the younger age groups, both of the curves of Fig. 1 would remain as high at the older as at the younger age levels. Actually, both curves of Fig. 1 exhibit very noticeable and consistent decrements at the uppermost age levels, thus indicating that both groups of physicists became progressively less productive at the older age levels. Obviously, the foregoing statements hold only for creative work of the highest order; it may or it may not hold true for quantity of output.

Fig. 1 reveals that, as compared with the age-curve which sets forth data for the earlier-born group of

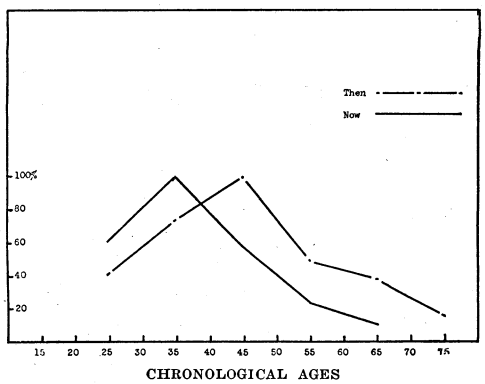

FIG. 1. Man's most creative years in physics: then and now. (Then) 60 contributions by 45 physicists born prior to 1785. (Now) 80 contributions by 44 physicists born from 1785 to 1867 inc. Data from Magie, W. F., "A Source Book in Physics." 1935.

physicists (the broken line), the curve for the more recently born group (the solid line) has the following characteristics: (1) It starts its ascent at the same age-interval, namely, at ages 20–29, inc.; (2) it rises more rapidly and it attains its peak ten years earlier, *viz.*, at ages 30–39 instead of at ages 40–49, and (3) it falls off at about the same rate of speed but, since the solid line starts its descent ten years earlier, the solid line is from 10 to 15 per cent. lower than the broken line at each age level from ages 45 to 65, inclusive.

Fig. 1 thus reveals that, as a group, the more recently born contributors to the science of physics have been somewhat younger at the time of making their world-famous contributions than were the earlier-born contributors. Somewhat similar findings have been obtained for the more recently born sub-groups of individuals who have contributed to the fields of geology, mathematics, invention, botany, pathology, classical descriptions of disease, medicine and public hygiene, literature, economics and political science, education and philosophy.[3] Since the findings for each of these sub-groups are presented herein in graphic form, they will require little comment. The general procedure for constructing the several age-curves has been similar for each type of eminent thinker. That is to say, for each of the sub-groups of contributors to a given field, an age-curve was drawn setting forth the average number of contributions per ten-year interval.[4] In each of these fields of endeavor it has been possible, therefore, to compare the output of approximately the earlier-born 50 per cent. with the output of the 50 per cent. that were more recently born.

Fig. 2 sets forth data for geologists, and Figs. 3 to 8, inclusive, set forth analogous information for

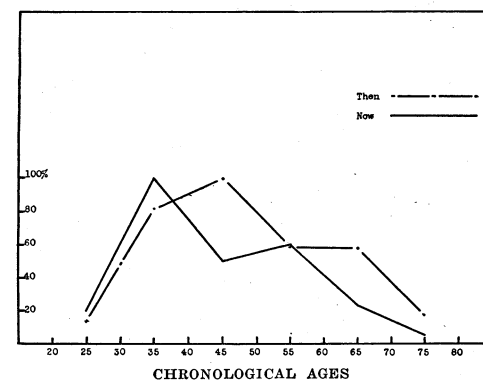

FIG. 2. Man's most creative years in geology: then and now. (Then) 84 contributions by 63 geologists born prior to 1800. (Now) 99 contributions by 65 geologists born from 1801 to 1857 inc. Data from Mather, K. F., and Mason, S. L., "A Source Book in Geology." 1939.

mathematicians, inventors, botanists, pathologists, classical describers of disease and contributors to medicine and public hygiene. For each of these types of creative thinkers the source from which data were obtained is given in the bibliography.[5-11] In general,

[3] In three fields of endeavor, namely, in chemistry, in astronomy and in oil painting, no significant age-change is discernible.

[4] Units of ten-year intervals will be used for the following age-curves unless otherwise specified. In constructing the graphs that accompany this article, the data for each of them were first reduced to a comparable basis by the following procedure: The peak of each statistical distribution was arbitrarily assigned a value of 100 per cent. and the other averages within the same statistical distribution were then assigned proportionate percentage values. For example, in Fig. 1, the peak of the distribution that is pictured by the solid line occurred at ages 30–39 inclusive. This modal value was taken to be 100 per cent. and the remaining frequencies by age-group were then computed and plotted as percentages of this modal value.

[5] K. F. Mather and S. L. Mason, "A Source Book in Geology." New York: McGraw-Hill Book Co., Inc., 1939. Pp. xxii–702.

[6] David Eugene Smith, "A Source Book in Mathematics." New York: McGraw-Hill Book Co., Inc., 1929. Pp. xvii–701.

these age-curves reveal that one or more of the comments already made with reference to Fig. 1 hold also for Figs. 3 to 8, inclusive.

Fig. 4 (inventions) is based upon data obtained from such well-known sources as "The Lincoln Library of Essential Information,"[7a] the "Standard Dictionary of Facts,"[7b] "The Scientific American Reference Book,"[7c] and so forth. Although in Fig. 4 the peaks of both age-curves occur at ages 30–39, it will be noted, nevertheless, that the curve for the more recently-born group (the solid line) rises more rapidly and it also

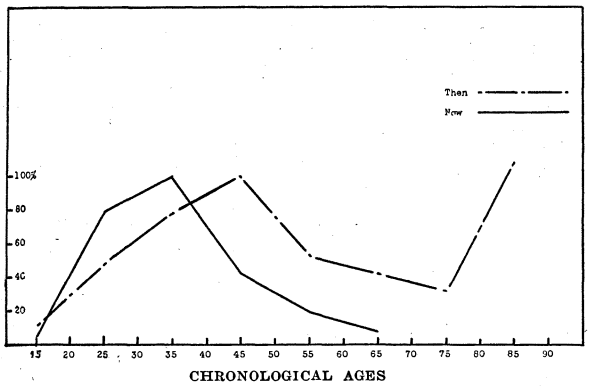

FIG. 3. Man's most creative years in mathematics: then and now. (Then) 54 contributions by 28 mathematicians born prior to 1748. (Now) 42 contributions by 27 mathematicians born from 1748 to 1848 inc. Data from Smith, D. E., "A Source Book in Mathematics." 1929.

falls off more rapidly than does the curve for the earlier-born individuals.

In Fig. 6 (pathology) the peaks of both curves likewise occur at ages 30–39, inclusive, and here too the

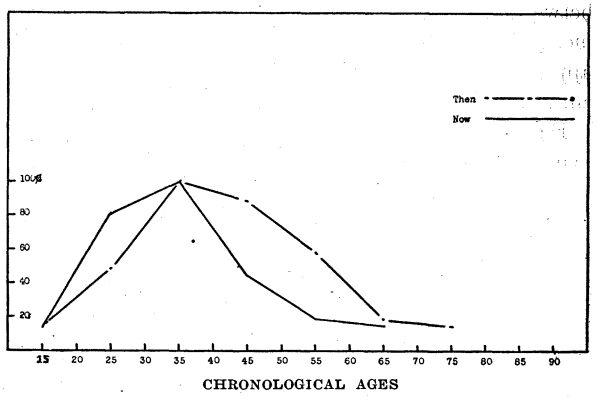

FIG. 4. Man's most inventive years: then and now. (Then) 154 inventions by 86 inventors born prior to 1750. (Now) 135 inventions by 86 inventors born from 1830 to 1850 inc. Data from various sources. See text.

curve for the more recently born group (the solid line) starts at a higher level and it also descends more rapidly than does the curve for the earlier-born. Fig. 6 thus suggests that, as compared with the more recently born group, the earlier-born group of pathologists were slower in starting to contribute and that they contributed more at the older age levels. It is, of course, possible that no genuine age-change has occurred as regards the average productivity of the several age groups but that only the time-lag between the date of discovery and the date of announcing the discovery has been decreasing during the past few centuries. Certainly, a large decrease in the amount of time-lag

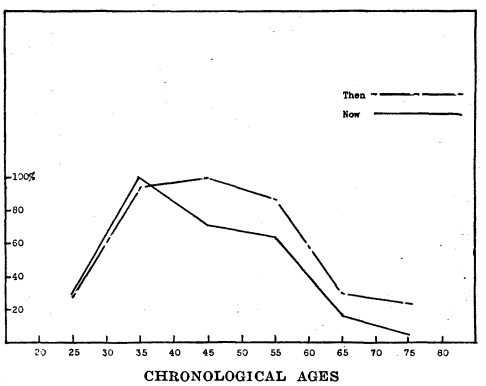

FIG. 5. Man's most creative years in botany: then and now. (Then) 91 contributions* by 53 botanists born prior to 1800. (Now) 144 contributions* by 50 botanists born from 1800 to 1854 inc. Data from Reed, H. A., "A Short History of the Plant Sciences." 1942.

* For the botanists it was not possible for the present writer to ascertain the exact number of different contributions. It was possible only to tabulate each time a dated contribution was mentioned in Reed's history. The same contribution may therefore have been counted more than once. The computations that were employed for constructing Figure 5 are based upon the foregoing procedure.

7 (a) "The Lincoln Library of Essential Information." Buffalo, New York: The Frontier Press Co., 1934. (Modern inventions are listed on pp. 1336 *ff.*) (b) H. W. Ruoff (editor), "The Standard Dictionary of Facts." Buffalo, New York: The Frontier Press Co., 1910. (c) "The Scientific American Reference Book." Compiled by A. A. Hopkins and A. R. Bond. Munn and Co., publishers. Scientific American Offices. New York: 1905. Pp. viii-516. (See especially pp. 218–224 and pp. 216–*ff.*) (d) E. E. Irvine (editor), "The World Almanac and Book of Facts for 1938." New York: Published annually by *The New York World Telegram.* 1938. Pp. 64–960.

8 H. S. Reed, "A Short History of the Plant Sciences." Waltham, Mass.: Published by the Chronica Botanica Company. 1942. Pp. x–320.

9 E. B. Krumbhaar, (editor), "Clio Medico: A Series of Primers on the History of Medicine." XIX. Pathology by E. B. Krumbhaar, New York: Paul B. Hoeber, Inc., Medical Book Department of Harper and Brothers. 1937. Pp. xvii–206. (See pp. 157 *ff.*)

10 Ralph Major, "Classical Descriptions of Disease." Springfield, Illinois: Thomas. 1932. Pp. xxvii–630.

11 F. H. Garrison, "An Introduction to the History of Medicine." Fourth edition. Philadelphia and London: W. B. Saunders Co., 1929. Pp. 996. (A chronology of medicine and public hygiene is given on pp. 809 *ff.*)

between date of discovery and the date of announcement thereof could account for much or even all of the apparent age-change that has been found in the present study.

Figs. 9 to 13, inclusive, are based upon composite lists of contributions. The procedure that was em-

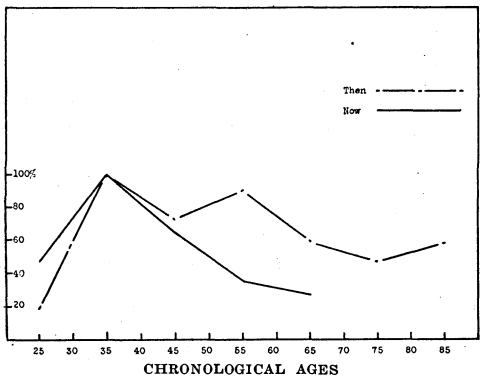

FIG. 6. Man's most creative years in pathology: then and now. (Then) 110 contributions by 88 pathologists born prior to 1773. (Now) 107 contributions by 84 pathologists born from 1773 to 1871 inc. Data from Krumbhaar, E. B., (editor). Clio Medica: "A Series of Primers on the History of Medicine." 1937.

ployed for obtaining each of these composite lists will be illustrated by describing the manner in which the data for the philosophical contributions were obtained. The most important philosophers were identified by canvassing more than 50 standard histories of philosophy. The foregoing procedure assumes: (1) That no

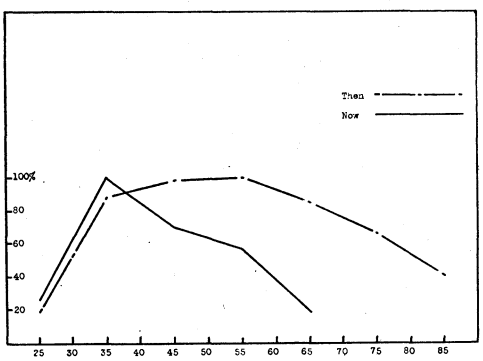

FIG. 7. Classical descriptions of disease: then and now. (Then) 67 classical descriptions of disease by 51 individuals born prior to 1759. (Now) 77 descriptions by 52 individuals born from 1760 to 1850 inc. Data from Major, R. H., "Classical Descriptions of Disease," 1932.

single authority is an absolutely safe guide; (2) that by careful collation of a large number of authoritative lists one can sift out the questionable names and be sure that no very important names have been overlooked, and (3) that the collective judgment of these professional historians is likely to be more valid than are the individual judgments when taken singly. It would seem to be a self-evident fact that a philosopher whose writings are mentioned and discussed in many of the standard histories of philosophy is likely to be

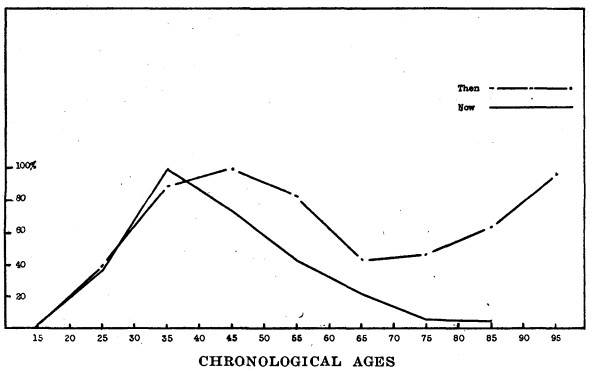

FIG. 8. Man's most creative years in medicine and public hygiene: then and now. (Then) 321 contributions by 215 contributors born prior to 1749. (Now) 407 contributions by 275 individuals born from 1750 to 1850 inc. Data from Garrison, F. H., "An Introduction to the History of Medicine." 1929.

more important as a philosopher than is another individual whose philosophical writings are cited and discussed in only a few histories of philosophy.[12]

In constructing Fig. 9 (philosophy) the writer has thus used the collective judgments of historians who

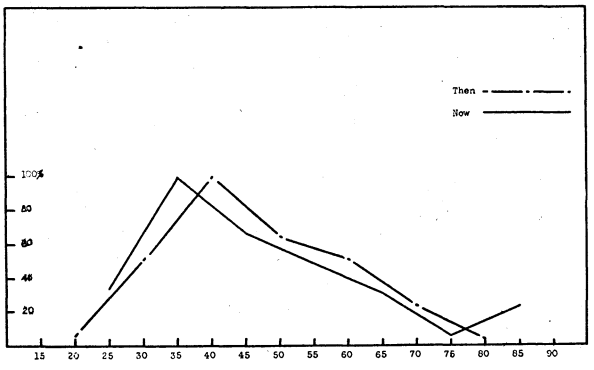

FIG. 9. Man's most creative years in philosophy: then and now. (Then) The one most significant work by each of 97 philosophers born prior to 1763. (Now) The one most significant treatise by each of 97 other philosophers born from 1764 to 1850 inc. Data from a composite list. See text.

have published their evaluations under their own signatures and who must, therefore, have tried conscientiously to cite and to discuss only the more impor-

[12] The names of 30 outstanding philosophers from various countries of the world are to be found in the *Psychological Review*, 1942, 49: p. 320, Table I. Important philosophical writings are listed on p. 322, Table II.

tant philosophical treatises. It also seems probable: (1) That this large number of independent critics did not concern themselves with the age factor; (2) that whether they were or whether they were not aware of the age factor, they probably have exhibited no constant prejudice for or against any one particular age group, and (3) that careful tabulation of the number of different histories in which a given philosophical treatise was cited and discussed should enable one to identify the really great philosophical works.

For each philosopher who wrote at least one book which appeared in as many as 5 different histories of philosophy, the philosopher's one most important treatise was ascertained. In selecting each philosopher's one most important writing it was assumed that the one treatise by a given philosopher which was cited and discussed in the largest number of standard histories was that particular philosopher's most important work. In this manner the 194 most important or significant works by each of 194 deceased major philosophers were identified. Fig. 9 reveals, both for the earlier-born 50 per cent. and for the more recently born 50 per cent., the average number of most important philosophical works that were either written or first published[13] during each ten-year interval of the authors' lives.

In the construction of Fig. 9 (philosophy), for the earlier-born group, the age intervals differ slightly from the age intervals that were employed in drawing Figs. 1 to 8 inclusive. In Figs. 1 to 8 inclusive, age intervals 20–29, 30–39 and so forth were employed. But, in constructing the broken line of Fig. 9, age intervals 15–24, 25–34 and so forth have been used. These latter age intervals were employed in constructing the broken line of Fig. 9 because it was found by trial-and-error that this method of plotting brings out more clearly the trend of the age changes that seem to have occurred as regards philosophical contributions.

Fig. 10 presents information regarding the chronological ages at which 190 notable authors either wrote or first published so-called "best books." The best books were identified in 1924 by Mr. Asa Don Dickinson, librarian of the University of Pennsylvania, who made a composite study of more than 50 "best book" lists. From Dickinson's[14] composite list the present writer identified the one "best book" by each[15] of 96 authors born prior to 1807, and also the one "best book" by each of 94 other authors who were born from 1807 to 1851 inc. In the construction of Fig. 10, no author's book was used unless the author had written at least one book which appeared as many as 5 times in Dickinson's composite list. Since most of the authors whose best books were employed in the construction of Fig. 10 wrote books which appeared more (some of them many more) than 5 times in the Dickinson composite list, it should be apparent that the foregoing minimum requirement for inclusion in Fig. 10 makes for a very severe selection. Indeed, for each kind of endeavor that is discussed herein, the criterion of selection is so high that the present study includes, with a few possible exceptions, only the *most* distinguished, who contributed within a given field, of whom there is historical record, and it includes (for each field studied) substantially all these.

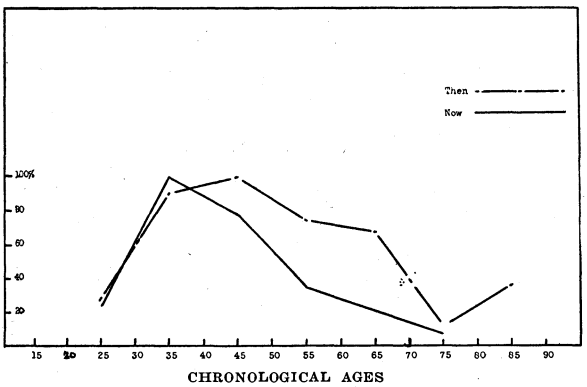

FIG. 10. Man's most creative years in literature: then and now. (Then) The one "best book" by each of 96 world-famous authors born prior to 1807. (Now) The one "best book" by each of 94 other world-famous authors born from 1807 to 1851 inc. Data from Dickinson, A. D., "One Thousand Best Books" 1925.

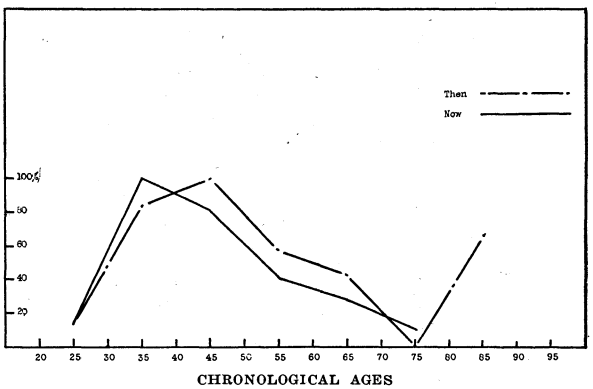

FIG. 11. Man's most creative years in education: then and now. (Then) The one most important treatise by each of 63 educational theorists born prior to 1743. (Now) The one most important writing by each of 60 other educational theorists born from 1744 to 1849 inc. Data from a composite list. See text.

[13] The dates of composition were employed whenever they were available. When dates of composition could not be obtained, the dates of first publication were used.

[14] A. D. Dickinson, "One Thousand Best Books," p. xii. Garden City: Doubleday, Page and Co., 1925. Pp. xvii–416.

[15] All authors for whom dates of birth and death and dates either of writing or of first publication were available.

Fig. 11 is based upon data obtained from 49 histories of education. The two curves of Fig. 11 reveal the ages at which the one most important book, report or educational plan was advanced or first published by each of 123 individuals, all of whom are well known in the history of education. No book, report or educational plan was employed in the construction of Fig. 11 unless it appeared in as many as 3 of the 49 histories of education. This was the minimum requirement for inclusion in Fig. 11. Obviously, most of the educational theorists whose works are included in Fig. 11 could have passed a much higher criterion of selection.[16]

Figs. 12 and 13 (economics and political science) are based similarly upon study of 20 books which deal

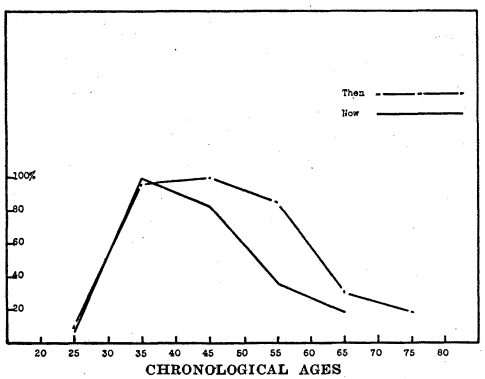

FIG. 12. Man's most creative years in economics and political science: then and now. (Then) The one most important treatise by each of 73 major contributors born prior to 1790. (Now) The one most important treatise by each of 69 major contributors born from 1791 to 1850 inc. Data from a composite list. See text.

with the history of those two subjects. Fig. 12 sets forth data regarding the one most important treatise by each of 142 individuals who wrote at least one book which appeared in as many as 4 of the 20 histories of economics and political science,[17] and Fig. 13 presents analogous information regarding 255 other individuals who wrote books which were cited and discussed in from 1 to 3 of the histories, *e.g.*, who wrote no book which appeared in as many as 4 of the 20 histories of economics and political science. Fig. 12 thus reveals the most creative years for each of two groups of major economists and political scientists and Fig. 13 sets forth comparable information for each of two groups of minor economists and political scientists. It seems apparent that for both the major and for the minor economists and political scientists the peaks of productivity were attained ten years earlier by the sub-groups that were more recently born.

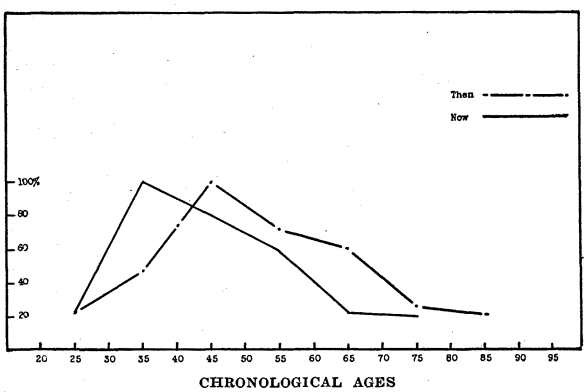

FIG. 13. Man's most creative years in economics and political science: then and now. (Then) The one most important treatise by each of 129 minor contributors born prior to 1790. (Now) The one most important treatise by each of 126 minor contributors born from 1790 to 1851 inc. Data from a composite list. See text.

CONCLUDING REMARKS

For 12 of the fifteen types of creative endeavor that have been mentioned in the present article, the contributions of the more recent era were made at younger age levels. For three of them, namely, chemistry, astronomy and oil painting, no significant age-change is evident. Just why 80 per cent. of the age-curves which reveal brilliant intellectual attainment should start their descents at earlier age levels for the more recently born individuals the present writer does not know. The following conjectures may account in part for the earlier peaks in the age-curves of the more recently born groups. However, they do not account for the more rapid descent of the age-curves of these sub-groups after the curves have attained their peaks.

(1) Chance factors have probably become less operative with the passage of time. (2) The early amateur investigators were more often self-educated; they had less opportunity to receive formal instruction and to experience the stimulation that is provided by groups of understanding colleagues. (3) The early workers possessed fewer ready-made tools or tech-

[16] The following is a list of the seven most outstanding educational treatises, giving the author, the book or treatise and the number of histories of education discussing it. J. J. Rousseau, "Emile," 40; J. A. Comenius, "Great Didactic," 38; John Locke, "Some Thoughts Concerning Education," 35; John Milton, "Tractate on Education," 35; Roger Ascham, "The Schoolmaster," 31; F. Froebel, "The Education of Man," 30; J. H. Pestalozzi, "Leonard and Gertrude," 30.

[17] The six most frequently discussed works in economics and political science, by author, book or treatise and number of histories of economics and political science discussing it follow. Adam Smith, "Wealth of Nations," 16; F. List, "Das Nationale System der Politischen Oekonomie," 14; T. R. Malthus, "Essay on Population," 14; David Ricardo, "On the Principles of Political Economy and Taxation," 14; Karl Marx, "Das Kapital," 13; J. S. Mill, "Principles of Political Economy," 13. Further research would no doubt change the relative amount of credit that is assigned to specific works. This change would probably not alter the shapes of the age-curves appreciably.

niques. These research devices had not yet been invented or discovered. (4) During the last few centuries, avenues of publication have increased very greatly in number. Moreover, both the demand and the reward for creative thinking have been growing. (5) According to Florian Cajori,[18] prior to about the beginning of the eighteenth century, mathematicians often deliberately withheld their discoveries as a means of preserving and enhancing their prestige (see Fig. 3). (6) The time-lag between date of discovery and the date of publication thereof may have been decreasing during the past few centuries.

Although the foregoing speculations may account in part for the finding that the contributions of the more recent era tend to occur at younger age levels, these speculations are rather inadequate. Perhaps it will be just as well if we confess our ignorance and ask not why this change has occurred but rather confine our attention to what has happened. At this point the present writer finds himself in hearty agreement with Professor Harvey B. Lemon, who, with reference to certain researches in the field of physics, has written:

> Our investigations into these things have but begun. What we do not ourselves understand any too well we cannot, naturally, explain fully to others.[19]

It has been suggested to the present writer that, whereas, in former days significant scientific contributions could be made often by youthful investigators who possessed relatively meager knowledge and background, to-day it may perhaps be necessary for the potential contributor to possess more extensive experience and a much larger fund of knowledge if he is to display effective and profound originality. It has also been argued that, because of our present greater average length of life, as compared with the average of previous centuries, maximum intellectual fecundity in the future will also tend to occur at older age levels.

The foregoing data reveal no factual basis for supposing that the most important creative work of the present day is being done by individuals who are older than the contributors of past centuries have been. Indeed, if any genuine age-change has been occurring (something more than a mere decrease in time-lag), the change seems to favor the younger rather than the older age-groups. And if a review of what has taken place in the past is an indication of what is likely to occur in the immediate future, it seems clear that there is no evidence whatever to support the hypothesis that future generations of creative thinkers will attain their peak output at increasingly older age levels. However, as was stated previously, this generalization does not hold for quantity of output but only for creative work of the highest merit.

OBITUARY

WILLIAM FOGG OSGOOD

WILLIAM FOGG OSGOOD was born in Boston on March 10, 1864, son of William and Mary (Gannett) Osgood. In July, 1890, he married Therese Ruprecht, by whom he had two sons and a daughter. In August, 1932, he married Céleste Phelps Morse, who survives him. He died on July 22, 1943.

Osgood was prepared for college at the Boston Latin School and became a member of the class of 1886. He took second-year honors in classics, and final highest honors in mathematics. There was little in the Harvard curriculum at that time to inspire a young man to give his life to mathematical research. The only member of the Mathematics Department, actively interested in scientific advance, was the youthful Benjamin Osgood Peirce, and his interest lay largely in the field of physics. But Osgood had early absorbed the idea that mathematics was the most difficult subject to be studied, and he meant to try for the biggest prize.

On graduation from Harvard he spent one more year in Cambridge as a graduate student, then went abroad for three years of advanced study in Germany. He spent the first two years in Göttingen, working especially under that prince of teachers, Felix Klein. His third year was in Erlangen, and there he took his doctorate. The years spent in Germany determined absolutely his whole future life. He married a German wife. He acquired such a mastery of German that his most important scientific writings were in that language. He adopted the German Weltanschauung to an extent that became somewhat embarrassing during the first World War. In the present crisis he saw matters in a different light. He received a mathematical impulse which guided his scientific thinking for the rest of his life.

Osgood returned to Harvard to teach in the autumn of 1890, thus beginning a connection which remained unbroken until the time of his retirement at the age of 69, in 1933. His was a distinguished and successful career. He saw the need for real improvement in the Harvard mathematical teaching. Byerly was an outstanding teacher in introductory courses, and J. M. Peirce was patient and conscientious, but there were others in the teaching force who lacked both

[18] F. Cajori, "A History of Mathematics," p. 133. Second edition. New York: The Macmillan Co., 1922. Pp. xiv–516.

[19] H. B. Lemon, "From Galileo to Cosmic Rays," p. 334. Chicago: The University of Chicago Press. 1934. Pp. xviii–450.