phenomena, as seen to-day, represent a phase in the evolution of thermal springs.

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HISTORIOMETRY AS AN EXACT SCIENCE

In the issue of Science for November 19, 1909, under the title "A New Name for a New Science" I proposed the term historiometry for that class of researches in which the facts of history have been subjected to statistical treatment according to some method of measurement more or less objective or impersonal in its nature. These researches have chiefly had in view the listing and grading of historical characters, either for the purpose of studying mental heredity or for the better appreciation of problems associated with the psychology of genius. Researches of this type are capable of a far greater expansion and application than is generally supposed. They can be applied to events as well as to individuals. They can, by treating the vast store of human records which exist in books as material for the construction of an exact science, work towards the solution of a wide range of historical problems, such as the causes underlying the rise and fall of nations or other fundamental questions in history.

Before anything can be done which shall give general satisfaction and agreement it will be necessary for this subdivision of science to justify itself, to measure its own shortcomings, to appreciate its own limitations, as well as to prove its own right to recognition of independent estate.

If we are to fathom historical causation by objective methods it is obligatory first to prove that history itself, as we commonly find it in the printed records, is a sufficiently valid account of what actually happened. Second, it is equally necessary to find proof that the objective methods correctly deal with these facts. It might be supposed that the second proof awaits the first; but this is not necessarily so. If the records themselves were very much at fault, so that the statements of historians were very far from ideal truth, or if the objective methods of collecting and analyzing these statements were subject to a large error (or if both these forces were in play) then it would be difficult to find wherein the trouble lay. But if, on the contrary, it fortunately be that history as we find it is in its important statements a fair representation of the truth, and if the methods of historiometry which deal with these records are also sound, then it is not difficult to prove both propositions at the same time.

I will give some instances to illustrate this, which show that such is the case for several types of historical records and for several methods of history measurement. This could not be done did we not possess some third criterion, some third standard of comparison of a non-historical nature. One such non-historical criterion is furnished by the known correlation ratios for resemblances between close blood relatives as determined in the anthropometric laboratory. These have been worked out and accurately measured for mental and moral traits, stature, head index and length of forearm. I have shown in "Heredity in Royalty"[1] that if the members of royal families are graded by the adjectives applied to them by historians and encyclopædists and then the coefficients of resemblance are measured between the near of kin, who have been so graded, these coefficients (historiometric) substantially agree with the anthropometric. Such would not be the case if historians perverted the truth greatly, or if for any other reason the truth were largely unattainable. To make this clear it is only necessary to think what the result would be if history were merely "a pack of lies agreed upon" as the extreme view puts it. We should then fail to properly pick out our true intellectual giants and runts. The result would be nothing but confusion. A whole series of errors would be distributed at random. This would act like rain on waves and flatten down to a common level the real differences between the individuals. The correlation measurements would fall and we should get no results comparable to those obtained from the delicate and ac-

[1] New York, Henry Holt, 1906.

curate measurements of the anthropometric laboratory.

Furthermore, any weakness in the method of grading, any failure to properly classify the great men in the high grades and the degenerates in their proper grades would work in precisely the same direction to lower the correlation coefficients. The supposed errors of history and the difficulties of grading act as two united strains of tension to pull the coefficients down towards zero, which would be the coefficient for random distribution. If the coefficient can stand the strain without declining, then, roughly speaking, we may conclude both that the historical foundation is just and that the method of procedure is sound.

There are two other illustrations of method which I would like to summarize here. One of these series of tests is the trying out of a standard biographical dictionary (historical persons) against two lists of contemporaries (non-historical persons) and all three in terms of still another set of facts, namely birthplaces of distinguished Americans. The second series of tests concerns the relative fame of Euripides *versus* Sophocles, the encyclopædias having been used and then this compared with expert modern criticism and both with the opinions of the Athenians.

As concerns American history, one fact is very evident at the start, whatever be the method of grading as applied to Americans or whatever be the mental eminence graded, some states in the union, some sections of the country, have produced more eminence than others far beyond the expectation from their respective white populations. In this regard Massachusetts always leads, and Connecticut is always second, and certain southern states are always behind, and fail to render their expected quota. I have already pointed out[2] that the ratios seem orderly for a first approximation. That is, the higher the grade of the individuals the greater and greater becomes the proportion of those born in Massachusetts. This may be expressed as a ratio, ρ into the random expectation. Thus if there were no forces at work beyond chance distribution the ratios for all sections of the country would be expressed by unity, $\rho = 1$. If there be found twice as many persons born in a certain locality as one would expect from the population let it be expressed as $\rho = 2$, three times as many, $\rho = 3$, etc. These ratios are easily computed and can be expressed as fractions or with decimals. I have computed these ratios for the thirteen original states, but will present here only the statistics from Massachusetts and Virginia.

It will be seen in Table I. that Massachusetts has never failed to produce twice as many eminent men as the population would lead one to expect, and has for some ranks and types of achievement produced about four times the expectation. ρ ranges between 2.1 and 4.7. Virginia, on the contrary, has but rarely produced as many as might be expected from the large white population and the ratios in the same table are either below the expectation or not significantly above it. The other New England states (statistics not here given) have all done more than their share, but always less than Massachusetts. New York gives a trivial though constant excess above the expectation. From here southward the ratios drop off suddenly, so that New Jersey, Delaware, Pennsylvania, Maryland, North Carolina and Georgia have always furnished less than their share. For South Carolina the ratios again rise and exceed the expectation, but only by the slightest measurable amount. North Carolina, of all the thirteen original states, has always had the worst record in the way of producing distinguished men; the ratios falling to about one quarter of what might be expected from the white population.

Regarding the tables for the two contrasted states, Massachusetts and Virginia, and following down through the columns marked "ratios, or number of times the random expectation according to the population at the approximate age of their birth," one sees first that the Massachusetts ratios run from 2.1 to 3.9 and the Virginia from 0.2 to 1.1. The higher Massachusetts ratios are associated

[2] "American Men of Science and the Question of Heredity," SCIENCE, N. S., Vol. XXX., No. 763, pp. 205–210, October 13, 1909.

with the lists of names in which the standards for admission to the lists are higher—that is, specially selected groups of the more eminent. Massachusetts also shows an extra merit when science or literature is alone considered, but this is merely an accentuation of some cause or causes which have enabled her to lead, no matter what type of success be the criterion.

There is also to be seen a probably significant gain in the ratios for Massachusetts from the census of 1790 to 1850. A further study of this special phenomenon might develop some interesting conclusions. The ratio also rises when only those in *Lippincott's* are considered who have received adjectives of praise. Nine tenths of the persons named in this dictionary are given a passing notice by the editors and nothing critical is said of their lives or their work beyond the barest record. About one tenth receive such adjectives of praise as "celebrated," "illustrious," "eminent," "famous," "noted," etc.

A priori we may suppose that these represent an extra superior group as compared with the other nine tenths. *A posteriori* the supposition is verified, because how else can be explained the rise in the ratio for Massachusetts from 2.8 to 3.8? If this "adjective method" did not select a superior group it would not raise the ratios, or in other words draw it further away from random hazard for which $\rho = 1$. The more accurately it seizes hold of the right persons and justly expresses real differences dependent upon natural causes the more it will raise this ratio. One can now see how it is possible in this way, and in similar ways, to actually test the validity of any method of selection. Its value depends, among other things, upon its ability to raise, or lower, a ratio in a proper degree, suitable to the case in hand, so that the ratios shall fit in, and harmonize with other ratios and other results.

If, for instance, the "space method," or the selecting the 234 men who have had the most space allotted to them in the dictionary, had not raised the Massachusetts ratio from 2.8 to any more than say 2.9 or 3.0 we might be justified in concluding that this method was inferior in accuracy to the "adjective method." As it turns out, it raises the ratio to 3.6. So one suspects that the "space method" is not quite as accurate as the "adjective method," since it does not raise the ratio as much though it deals with a smaller group. Of course one instance like this does not decide anything. I merely give it as an illustration of the ways in which historiometry may proceed.

I have also essayed a new method, namely selecting from *Lippincott's* a list composed of all those Americans whose biographies have been written and published in separate works. This constitutes a very small and presumably correspondingly select group, 129 in number. The ratio for Massachusetts is here seen to rise to 3.9, practically the maximum. It should of course do so if the method is sound and is successful in seizing hold of the right men. This may prove a very accurate, practical and rapid method of objectively listing great men in ancient or modern history, subject of course to such limitations and adjustments as special problems may require.

It can be seen that the general raising of the ratios is in no way dependent on the dictionary containing a large number of clergymen and writers. As a matter of fact, more than a third of the names are those of lawyers, bankers, merchants, politicians, government officials, soldiers, manufacturers and engineers. Here by narrowing the list from 1,266 to 232 and dealing with only a small group, we raise the ratio from 2.4 to 3. It might be supposed by some that a greater attention is shown Massachusetts by writers of books, biographies and histories because these writers live in the neighborhood. "Lippincott's Biographical Dictionary," however, is published in Philadelphia. Still it may be influenced by previous writings and earlier biographical dictionaries published in the neighborhood of Boston. If this is so to any appreciable extent then we should expect the ratio for Massachusetts to fall when present-day persons are graded by methods which have either nothing or little to do with historical traditions.

TABLE I

List of Names	Total in the List Born in U. S. A.	Number Born in Massachusetts	Number Born in Virginia	Ratios, or Number of Times the Random Expectation According to the Population at the Time of their Birth	
				Mass.	Virginia
Lippincott's "Biographical Dictionary," edition of 1895.	3,227	711	231	$\rho = 2.8$	$\rho = .6$
Same dictionary.					
Americans born A.D. 1785–A.D. 1794	302	75	22	$\rho = 2.1$	$\rho = .6$
Born A.D. 1795–A.D. 1804	370	79	25	$\rho = 2.2$	$\rho = .6$
Born A.D. 1805–A.D. 1814	464	96	23	$\rho = 2.6$	$\rho = .5$
Born A.D. 1815–A.D. 1824	513	97	33	$\rho = 2.9$	$\rho = .8$
Born A.D. 1825–A.D. 1834	363	74	19	$\rho = 3.6$	$\rho = .8$
Born A.D. 1835–A.D. 1854	343	58	15	$\rho = 3.5$	$\rho = .6$
Average of the above six lists	2,355	479	137	$\rho = 2.8$	$\rho = .65$
Same dictionary, Americans who have received any adjectives of praise	320	95	23	$\rho = 3.8$	$\rho = .6$
Same dictionary, Americans who have been allotted extra space (20 lines)	234	67	20	$\rho = 3.6$	$\rho = .8$
Same dictionary, Americans about whom books have been written	129	39	14	$\rho = 3.9$	$\rho = .9$
Same dictionary, practical types only. Bankers, merchants, lawyers, politicians, government officials, engineers, manufacturers, soldiers	1,266	235	143	$\rho = 3.4$	$\rho = 1.03$
Same dictionary, selected list of the greater among the practical types. (Adjective, space and biographical method combined.)	232	60	29	$\rho = 3.0$	$\rho = 1.1$
"Who's Who in America," edition 1908-09	14,227	1,650	493	$\rho = 2.6$	$\rho = .9$
"Who's Who in America," practical types only (initials A–C)	1,131	132	33	$\rho = 2.5$	$\rho = .8$
"Who's Who in America," lawyers, judges, congressmen, government officials (initials A–C)	580	60	23	$\rho = 2.2$	$\rho = .9$
"Who's Who in America," engineers, inventors, architects (A–C)	134	16	3	$\rho = 2.5$	$\rho = .5$
"Who's Who in America," army and navy (A–C)	170	18	5	$\rho = 2.5$	$\rho = .7$
"Who's Who in America," business men, financiers, railway officials, manufacturers (A–C)	247	38	2	$\rho = 3.2$	$\rho = .2$
"American Men of Science," 1906, all persons	about 4,000	436	not yet calculated	$\rho = 2.7$	
"American Men of Science," 1906, the leading thousand.	867	134	14	$\rho = 3.4$	$\rho = .4$
"American Men of Science," 1910, the leading thousand.	874	131	17	$\rho = 3.4$	$\rho = .5$
Hall of fame (list slightly extended as in SCIENCE, N.S., Vol. XXXII., No. 813, p. 158)	50	20	7	$\rho = 3.3$	$\rho = .9$

Two such methods of grading we fortunately possess in the compilations known as "Who's Who in America," and "American Men of Science." The ratios for Massachusetts do not fall. They dove-tail in with the ratios from *Lippincott's*. Hence we may conclude that the differentiations found in *Lippincott's* are not caused by unjust historical tradition and, furthermore, as far as one can see they are not in part caused by the same. "Who's Who in America" has been often used as an objective basis for sociological inquiries, but the criticism has been made that this book gives undue inclusion of authors and professors. I think this criticism is unjust. About forty per cent. of the whole fall under the more practical types enumerated in Table I. These I have considered separately as far as the initials A, B and C. They yield a ratio for Massachusetts of $\rho = 2.5$, which is very close to that for the whole book $\rho = 2.6$. The same for *Lippincott's* is $\rho = 2.4$, which is not in its exact theoretical position, as it should be higher than that drawn from "Who's Who in America." It will, of course, be appreciated that the clearing up of small disagreements like this requires further analysis and the computation of the probable errors.

The ratios from Virginia I present in this abstract merely as a general contrast to Massa-

chusetts. I prefer to make further statistical inquiries before attempting to interpret their meaning.

The third series of tests which illustrate the exactitude of historiometry are drawn from comparative studies of the fame of Euripides and Sophocles. In SCIENCE, October 7, 1910, Mr. C. A. Browne called attention to the fact that Sophocles received the first prize from the Athenians twenty times, and Euripides only four times, while since their deaths various writers from Plato to Emerson have referred to and quoted Euripides more than Sophocles. Mr. Browne also shows that both Curtius and Grote, and biographical dictionaries, and encyclopedias as well, allot more space to Euripides than they do to his elder rival. This seems to indicate that the opinion of the Athenians has been reversed by posterity, but the real explanation I have found to be otherwise.

TABLE II

AUTHORITIES	SOPHOCLES			EURIPIDES		
	Space Lines or Pages	Adjectives		Space Lines or Pages	Adjectives	
		Pro	Con		Pro	Con
Bergk, "Griechischer literaturgeschichte," 1894	110 pp	128	28	137 pp	100	64
Bernhardy	74 pp	71	23	116 pp	105	97
Croiset	57 pp	115	13	71 pp	132	57
von Christ	34 pp	46	3	40 pp	35	20
Curtius	200 ls	25	0	773 ls	36	20
Müller and Donaldson	25 pp	31	3	30 pp	17	14
R. C. Jebb	11 pp	16	0	16 pp	24	11
Gilbert Murray	19 pp	31	4	28 pp	15	6
Jevons	11 pp	14	0	13 pp	19	9
ENCYCLOPEDIAS						
Meyer's "Konvasations Lexikon"	109 ls	9	0	126 ls	8	2
Brockhaus' "Lexikon"	112 ls	6	0	161 ls	2	1
"La Grande Encyclopédie"	298 ls	27	1	178 ls	5	1
"Encyclopaedia Britannica," 1890	550 ls	22	0	995 ls	10	4
"New International Encyclopedia"	207 ls	10	2	181 ls	7	3
Lippincott's "Biographical Dictionary," 1892	52 ls	8	0	45 ls	6	0

It appears that the problem that Mr. Browne proposes is a very delicate one. These two great Greek dramatists stand in such an exalted position and so close to one another, both being near the extreme range of human genius, that probably not two hundred individuals who have ever lived have exceeded them in eminence.[3] Therefore, compared with all men of all historical time, these two are almost merged in something like a point at the extreme end of a line. It is like splitting and measuring the components of a binary star at a great distance. It would be no discredit to any objective method of differentiation if it failed to give interpretable conclusions. As it is, it turns out that the problem presented is just within the limits of historiometric discrimination so that the figures yield uniformity and repetition warranting real conclusions.

I have extended Mr. Browne's list and have found confirmation of the statement that more space is devoted to Euripides than to Sophocles. This would leave the impression that Euripides is to-day frankly considered the greater of the two, which is not the impression that one gains by even a cursory reading of the printed matter so spaced. Furthermore, I am informed by John Williams White, Professor of Greek, Emeritus in Harvard University, that for the last hundred years the general estimate of scholars has placed Sophocles above Euripides. This is precisely the conclusion which is obtained from the extraordinary character of some of the terms and sentences of eulogism which one finds applied to Sophocles. In these same authorities one never finds for Euripides anything like the following: "There has hardly been any poet whose works can be compared with those of Sophocles for the universality and durability of their moral significance . . . of all poets of antiquity Sophocles has penetrated most deeply into the recesses of the human heart" (Müller and Donaldson). "He renders tragedy a perfect work of ideal art" (R. C. Jebb). Occasionally the direct comparison is

[3] Conf. J. McK. Cattell, *The Popular Science Monthly*, February, 1903, p. 359.

made and then Euripides suffers; for instance, as when Gilbert Murray says:

> No wonder Sophocles won four times as many prizes as Euripedes. . . . Sophocles shows at times one high power which but few of the world's poets share with him. . . . in the second Œdipus there is a certain depth of calm feeling unfettered by any movement of mere intellect, which at times makes the subtlest and boldest work of Euripides seem "young man's poetry" by comparison.

It can be easily seen that this general impression can be checked up and is unfailingly expressed by each ratio of the adjectives of praise (pro) against those of dispraise (con). For every single authority consulted the answer is the same,—the proportionate ratio favors Sophocles.[4]

The "space method" fails here to give a verdict agreeing with modern and ancient opinion probably for special reasons peculiar to the case. More plays of Euripides are extant and there is more to be said in the way of adverse or qualifying criticism. It is not to be denied that the interest in Euripides is, and always has been, intense, perhaps greater than in Sophocles, but the position of the latter is more majestic and more sublime. The lexicons alone would have given this conclusion in a few minutes reading. All these facts, in connection with those taken from Lippincott's dictionary, indicate that the "adjective method" is a very delicate way of measuring small differences if for any reason it is desirable to do so.

The questions here touched upon concern only the individuals, but I know from material as yet unpublished that the quantitative objective method can be applied to events as well as to persons. If its validity for the study of individuals can be securely grounded, then its application to events will naturally follow and will be thereby the more easily and surely established.

Space has permitted only a brief abstract, but I think that enough has been given to prove that researches of this nature furnish harmony and order, intertwine and mutually support each other, form an organic structure, and are entitled to recognition among the exact sciences. It must be remembered that exactitude in science is a relative term. Abstract mathematics may be exact, but no science of physical measurement is really exact. Astronomy, which is usually thought of in this way, only gives an approach towards an ever-expanding ideal. No two observers have ever quite agreed upon the latitude of the Greenwich observatory and the last transit of Venus was, if I remember rightly, in comparison with the computed prediction, some eleven seconds off. All we ask is that the exactitude shall be sufficient for the practical needs of the problem in hand.

I think it must be agreed that this first synthesis and coordination of isolated researches presents a very encouraging picture. It indeed gives proof that a workable instrument has been obtained capable not only of dealing with questions as intricate as human nature and its attributes, but actually at the same time demonstrating the essential validity of the historical data on which are based the percentile grades, ratios, correlations or other super-structure. This latter conception is to me the most interesting side of the whole matter. It has usually been impossible to scientifically refute those critics who claim that the so-called facts of history are so uncertain and subject to so great an error and prejudice that it is unsafe to build conclusions upon them by statistical methods. They have not of course ever known that such was the case nor have they ever had any way of estimating how far the records of history, as they exist in standard works, encyclopedias and biographical dictionaries, actually deviate from the absolute truth. It has been assumed, on the other hand, by those who have been engaged in grading historical characters, that the records represent a fair approximation towards the ideal truth. The human record which we call history stands somewhere between two extremes, somewhere between the quagmire of complete falsehood and heights of perfect truth. It is possible as we go on to appreciate, with closer and

[4] In this part of the work I have had the assistance of Mr. A. A. Jenkins, of the Harvard Law School.

closer accuracy, just what deviation from ideal truth any great set of historical records contains.

Such researches give promise of at last furnishing the long-sought correct method of penetrating the tangled and perplexing jungle known as philosophy of history. This domain of thought is to-day in poor esteem among those who, as historians of the modern school, seek in documentary sources to reconstruct the past around some central theme, some individual age or nation. No wonder these careful investigators have become disgusted with the *a priori* dogmatism, the partizan spirit, the free generalizations from half truths and the eternally conflicting conclusions. Historical philosophers, in their desire to explain everything at once, have been content to formulate theories and then pick from the totality of history, selected facts to support them. With methods highly subjective, and carrying a large personal equation they could not help but find exactly what they wished. The ways of inductive science may be slow at first, but even a small nucleus of collected and coordinated facts soon grows with astonishing rapidity; and every objectively established piece of work makes it, with accelerated speed that much easier to progress along lines of certainty and exactitude.

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SCIENTIFIC NOTES AND NEWS

LORD CURZON will succeed Major Leonard Darwin as president of the Royal Geographical Society.

THE Bessemer gold medal of the Iron and Steel Institute, London, will, this year, be awarded to Professor Henri Le Chatelier, the French metallurgist. The Andrew Carnegie gold medal for 1910 will be awarded to M. Félix Robin, of Paris.

A COMPLIMENTARY dinner was given on March 29 by former students of King's College Hospital to Sir David Ferrier, M.D., F.R.S., to congratulate him on receiving the honor of knighthood.

DR. LUCIUS L. HUBBARD has been appointed regent of the University of Michigan. He has been instructor in mineralogy at the State Mining School at Houghton, Mich., and was state geologist from 1893 to 1899.

MR. GEORGE HENRY LIVENS, B.A., has been elected to a fellowship at Jesus College, Cambridge. His subject is mathematics.

DR. EDNA CARTER, instructor in physics at Vassar College, has been awarded the Sarah Berliner research fellowship for women. She will continue her work in physics at Cambridge under Professor J. J. Thomson, and in the laboratory of Professor Wein, of Würzburg, where she received her doctorate.

THE annual awards of the Royal Geographical Society are announced as follows: The two royal medals have been awarded, the Founder's to Colonel P. K. Kozloff, and the Patron's to Dr. J. Charcot. The Victoria Research Medal has been given to Captain H. G. Lyons, the Murchison Bequest to Dr. Wilfred Grenfell, the Gill Memorial to Captain G. E. Leachman (Royal Sussex Regiment), the Back Bequest to Dr. Arthur Neve, and the Cuthbert Peek Fund to Mr. R. L. Reid.

DR. H. F. MOORE, of the U. S. Bureau of Fisheries, has sailed for Rome where he will represent the Bureau at the fifth International Fishery Congress to be held May 26–31. Before returning he will visit the coast of Algiers for an examination of the sponge fisheries.

AN expedition under Mr. Homer B. Dill, of the State University of Iowa, has left San Francisco for Laysan Islands in order to study the bird life and bring back specimens for an extensive group to be placed in the museum.

PROFESSOR F. E. LLOYD, of the Alabama Polytechnic Institute, is planning a trip into the Arizona Desert this summer, in order to continue his botanical researches in desert plant life.

ACCORDING to the *Bulletin* of the American Mathematical Society, Professors E. R. Hedrick, of the University of Missouri, and J. I. Hutchinson, of Cornell University, have been