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Franz Boas and Statistics

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FRANZ BOAS WAS, beyond all doubt, the Father of American Anthropology," claimed a Ph. D. candidate in 1979 in the conclusion of his dissertation on Franz Boas.[1] It is not surprising, therefore, to note that historians in general, and historians of anthropology in particular, have a special interest in Boas. Many excellent accounts have been written about Boas from different perspectives; most notably, there are George W. Stocking's intellectual history, Marshall Hyatt's biography, and Hamilton Cravens's institutional history, not to mention numerous memoirs written by Boas's disciples and followers in the years following his death in 1942.[2] These historical treatments have greatly improved our understanding of Boas's thinking and his role in the early days of American anthropology. It has been agreed that Boas insisted upon the autonomy of anthropology as a science and defended his discipline from intrusion by natural scientists, in accordance with the general pattern of disciplinary development described by Warren O. Hagstrom.[3] Marginal in a double sense (having moved from physics to anthropology and from Germany to America) and with a deep abhorrence of authority, Boas was well-suited to undertake the task of transforming American anthropology from an amateur's hobby into a science.[4] There is, however, no complete consensus regarding the nature of Boas's achievements. While agreeing upon the importance of his efforts to separate anthropology from established natural sciences, especially biology, historians have nonetheless different answers to the question of *how* Boas successfully safeguarded anthropology from interventions of natural scientists.

It has often been suggested that Boas found a unique method for anthropology—the historical method—as opposed to the experimental, deductive methods popular in the natural sciences. Stocking, for exam-

ple, has traced Boas's intellectual roots to his native Germany, where both Rankean and Hegelian philosophy of history had influenced Boas in his youth. For Stocking this intellectual background explains why Boas as an anthropologist was partial to the historical method but suspicious of the use of deductive methods.[5] This line of approach suggests that it was the historical method that Boas employed to demarcate anthropology from the natural sciences. However, Boas did not restrict the historical method to anthropology. To Boas, the historical method was equally applicable to studies of all phenomena, cultural as well as physical, and the decision to choose either the historical method or the deductive method depends entirely on the researcher's personal preference.

> Our inquiry leads us to the conclusion that it is in vain to search for an answer to the question, Which of the two methods is of a higher value? as each originates in a different desire of the human mind. An answer can only be subjective, being a confession of the answerer as to which is dearer to him,—his personal feeling towards the phenomena surrounding him, or his inclination for abstractions; whether he prefers to recognize the individuality in the totality, or the totality in the individuality.[6]

Therefore, Boas did not delineate the border of anthropology by the uniqueness of its historical method. Rather, his emphasis on the historical method only showed his own preference of methodology in a field where he conducted research.

It has also been suggested that Boas found a unique area of study for anthropology—cultural phenomena—as opposed to physical and biological phenomena, which had already been the domain of the natural sciences. "The Boasians," Hamilton Cravens argues, held the "culture" theory to be "an indispensable intellectual weapon, for it permitted them to preempt man's cultural behavior as their special area of expertise."[7] However, cultural anthropology was only one branch of anthropology. Cravens's answer can, at best, account for Boas's claim for autonomy of that branch of anthropology. Surely Boas was not willing to surrender other branches of anthropology, such as physical anthropology, to natural scientists. Although Boas is best known for his work in cultural anthropology, he did research in physical anthropology all his life and tried to raise the standard of American physical anthropology as a part of his program of professionalizing anthropology. One of his letters in 1895 reveals his deep concern with physical anthropology:

Your remarks the other day in regard to your desire to see some work in physical anthropology done in Philadelphia interested me deeply because they refer to that branch of anthropology which is unduly neglected in our country and for which I am struggling along—so far practically alone.[8]

Ironically, Boas's work in physical anthropology has also been "unduly neglected" by historians for much the same reason that Ales Hrdlicka gave for its neglect in Boas's own time. A leading physical anthropologist and a contemporary of Boas, Hrdlicka lamented that Boas's work in physical anthropology was "predominantly statistical" and that while he had trained "a number of original workers in linguistics and ethnology," he had produced "none in somatology."[9]

Attempts to characterize the essence of Boas's views on anthropology have failed largely because they have not taken a comprehensive view of his anthropological interests. Historians often have the tendency of focussing on historical events that are most relevant to us and overlooking what might be most relevant to historical figures involved. A scientist's thinking is more or less coherent. If we are to understand Boas properly, we cannot limit ourselves to discussions of his historical methodology or his contributions to the culture concept. For Boas's statistical matters were as integral to his definition of anthropology as a science as were questions of the historical method, culture, or linguistics. For this reason, I believe that we will have a better understanding of Boas's thinking after exploring his statistical work, even though it has been accurately stated that "Boas' statistics did not stand as a system by themselves (as was the case with Pearson)."[10] Additionally, an analysis of Boas's statistical endeavors can also shed light upon the history of statistics itself. Donald A. MacKenzie has claimed that the ideology of the British intellectual middle class in the late nineteenth and early twentieth century gave rise to the eugenics movement and subsequently to the establishment of statistics as a science.[11] Boas, who was in contact with the British founders of eugenics and modern statistics, provides a unique test of the MacKenzie hypothesis.

Statistics and Anthropology

The method of American anthropology in Boas's day has been characterized as "empty empiricism."[12] However, Boas was not a simple-minded empiricist whose sole interest was "butterfly collecting." Aware of the loss of essential detailed information in generalizing, Boas

was certainly more cautious than were many of his contemporaries not to make premature generalizations. But Boas never intended to collect isolated data for their own sake. On the contrary, his interest was "the whole phenomenon and not its elements."[13] In fact, studying groups was the distinctive feature of anthropology from which Boas drew the dividing line between anthropology and other sciences:

Anthropology deals with the bodily form, the physiological and psychological functions, and the behavior of groups of men. It differs from many aspects of anatomy, physiology, and psychology in so far as these sciences are interested primarily in the typical behavior of the individual, whereas the group is the center of interest for the anthropologist.[14]

They [the anatomist, physiologist, and psychologist] deal primarily with the typical form and function of the human body and mind. . . . To the anthropologist, on the contrary, the individual appears important only as a member of a racial or a social group.[15]

For Boas, groups became the focus of anthropological study, taking the position of the typical individual in the natural sciences. Unlike the natural scientist, whose task was to describe regularities of the typical individual, Boas believed, the anthropologist should reveal information concerning groups as a whole.

His definition of anthropology called for an innovation in methodology as a necessity. The experimental, deductive methods characteristic of the natural sciences were no longer applicable to the study of anthropological phenomena, which were "variables" that "give different quantitative results when measured at different times, because the governing conditions are complex and never quite the same."[16] What method, then, did Boas have to offer for the anthropologist as a parallel to the experimental method serving for the physicist? Statistics. "Phenomena of this type," Boas asserted, "can be handled only by statistical methods."[17] Through the use of statistics, Boas believed, detailed data were recorded and manipulated without the danger of oversimplification. Therefore, statistics provided the ideal tool for the study of individuals in relation to their groups. This explains why Boas spoke highly of the statistical contributions of Francis Galton and Karl Pearson and was so impressed by Tylor's application of statistics to sociological problems that he once naively hoped that eventually everything could be solved by statistical methods.[18]

Boas lived through the period when a drastic transformation of methodology in social science took place. Victor Hilts calls the period "The Statistical Revolution."[19] Crucial to this transformation was the work of Francis Galton. Before Galton, Quetelet's influence dominated the area of statistical study of man. The contrast between Galton's and Quetelet's views on statistics paralleled that between Boas's anthropology and the anthropological tradition before him.

Adolphe Quetelet, a mathematician and astronomer with strong humanistic interests, is today credited as the first to apply systematic statistics, especially "the law of error," confirmed by astronomical observations, to the human being. Influenced by Enlightenment thought, Quetelet was convinced of the possibility of a "social physics" through the application of statistics. By averaging, Quetelet argued, one could discover the essence of mankind, since the average would not reflect the apparent irregularities. As this statistical method had been successful in astronomy, "why should not we endeavour to follow the same course in respect to man?"[20] Central to Quetelet's "social physics" was thus the idea of the "average man," or the "social man": "The average man, indeed, is in a nation what the centre of gravity is in a body; it is by having that central point in view that we arrive at the apprehension of all the phenomena of equilibrium and motion."[21]

> The *social* man, whom I here consider, resembles the centre of gravity in bodies: he is the centre around which oscillate the social elements—in fact, so to speak, he is a fictitious being, for whom every thing proceeds conformably to the medium result obtained for society in general. It is this being whom we must consider in establishing the basis of social physics, throwing out of view peculiar or anomalous cases, and disregarding any inquiry tending to show that such or such an individual may attain a greater or less development in one of his faculties.[22]

Through the "average man," Quetelet was able to reduce the complexity of cultural and physiological phenomena to abstractions similar to those in the physical sciences, where deviations from averages were commonly disregarded as caused by numerous accidental, independent factors. Quetelet also started the practice of equating the "average man" with the human "type," which he used as the standard for normality. Deviations from the "average man" or human "type" was considered as imperfection, "disease," or even "monstrosity."[23] Ernst Mayr has traced this tradition of thinking to Plato's *eidos* and named it "typological thinking" in contrast with the "population thinking" which Mayr argues originated with Charles Darwin.[24] For the "typologist," types are real,

constant, invisible, and perfect entities, while everything in the real world is only an imperfect replica of a hidden type. Quetelet's discovery of the applicability of the "law of error" in the "science of man" led him to echo the Platonic conviction that underlying human types existed and to believe that they could be revealed through the process of averaging.

Few sociologists accepted Quetelet's "social physics." But many anthropologists followed his steps in equating a racial type with the average characteristics of a race. One classical expression of this equation was given by Paul Topinard, a leading nineteenth-century physical anthropologist. Topinard shared with his teacher, Paul Broca, the idea that human types "are abstract, ideal concepts." Although "at the present time rarely, if indeed ever, we discover a single individual corresponding to our racial type in every detail," he asserted, "It exists for us nevertheless."[25] For Topinard, racial differences were as great as the differences observed between species, and thus there were "pure races" that are distinct from each other. Topinard justified his assertion in Quetelet's terms:

> By *human type* must be understood the average of characters which a human race supposed to be pure presents. In homogeneous races, if such there are, it is discovered by the simple inspection of individuals. In the generality of cases it must be segregated. It is then a physical ideal, to which the greater number of the individuals of the group more or less approach, but which is better marked in some than in others.[26]

If in biology it was Darwin who first challenged the "typological thinking" with "population thinking," in anthropology it was Darwin's cousin, Francis Galton. A great traveller, Galton spent a large portion of his youth among Africans, Arabs, and Spaniards, and was exposed to the enormous diversity of human beings in such a way that for him "individual differences . . . were almost the only thing of interest."[27] Not surprisingly, Galton's sensitivity to differences led him to consider actual distributions rather than averages. Since "the knowledge of an average value is a meagre piece of information," he wrote in *Natural Inheritance*, "we want to learn how the quality is distributed."[28] In contrast with Quetelet, who paid close attention to averages but ignored deviations, Galton was particularly concerned with the problem of variability. As a result, he was very upset with the traditional term "probable error," which made sense in astronomical measurement but was misleading when used in the study of man, as the term "error" seemed to imply undesirable, unreal, small quantities caused by measurement. Since for

Galton deviations were no less real, no less significant, and no less meaningful than averages, he could not tolerate the continued usage of "probable error":

The term Probable Error, in its plain English interpretation of the *most* Probable Error, is quite misleading, for it is *not* that. . . . Moreover the term Probable Error is absurd when applied to the subjects now in hand, such as Stature, Eye-colour, Artistic Faculty, or Disease. I shall therefore usually speak of Prob. Deviation.[29]

It was because of his primary concern with individual differences and variabilities rather than with averages that Galton discovered the phenomenon of "reversion" or "regression" and the idea of "co-relation" or "correlation." In Galton's statistical work, variability for the first time received serious attention and analysis.[30]

Boas is well known for his harsh criticisms of evolutionary anthropologists who explained cultural phenomena as the product of an inevitable evolutionary sequence. But this is only a half picture of his relation to evolutionists. As Mayr has observed, Darwin played a revolutionary role in changing traditional "typological thinking" into "population thinking."[31] This was the aspect of the evolutionary theory that Boas embraced and used to refute the evolutionary anthropologist. As early as 1887, Boas praised Darwin's evolutionary theory for first advocating "that the object of study is the individual, not abstractions from the individual under observation."[32] In battling the evolutionary anthropologist, Boas used precisely this argument: a thorough study of unique individual events should be primary to the construction of abstract evolutionary laws. A persistent skeptic, Boas criticized all theories that pretended to explain human behavior in broad and sweeping terms: cultural evolutionism, eugenics, and Mendelism.[33] He sometimes remarked that the discovery of laws governing human nature could be an ultimate aim of anthropology, but he argued that the time for the formulation of these laws had not yet come and therefore that the task of his own generation should remain limited to the level of data collection. For Boas, then, sound data without theory was preferable to speculative theory without supporting data.[34]

It might seem paradoxical that Boas, the founding father of cultural relativism who fought all his life against racism and eugenics, should have had close intellectual ties with Galton, who "is often remembered as a dilettantish racist who founded the eugenics movement."[35] Boas,

however, was able to distinguish between the value of a scientist's methods and his ideological commitments; and he often judged the merit of a scientific work by the appropriateness of its methodology. In his efforts to transform American anthropology into a science, Boas realized that the "older sciences . . . have achieved where we are still struggling with methods," and was prepared to grasp any methodological tools that he considered to be "scientific."[36] It was in this spirit of methodological receptivity that Boas inherited Galton's way of statistical thinking without as a consequence accepting Galton's ideological convictions about race and heredity. Boas thus provides a counter-instance to MacKenzie's claim that not only the rate of development of science but contents of scientific activities themselves are closely linked to ideology.[37]

Galton's influence on Boas is most conspicuous in Boas's rejection of Quetelet's concept of types. Like Galton, who criticized the practice of attaching "every one of the meanings . . . to the vague but convenient word 'type,' "[38] Boas was also opposed to reification of types, which had been frequently accepted by his fellow anthropologists: "The naive classification of human types does not represent a grouping according to biological principles, but is based on subjective attitudes. Nevertheless, there is a tendency to give biological reality to classifications arrived at quite irrationally and dependent upon previous individual experiences."[39] While critical of the misuse of types, Boas, nevertheless, continued using the term "type" in an amazing frequency—indeed in almost all of his published works concerning racial differences—only because his concept of types was no longer the traditional one. For Boas, types were not equated to averages, as they had been for Quetelet, but were loosely defined as "merely representing a series of forms"; and "the description of types must therefore be an enumeration of the frequencies of individuals of distinctive forms."[40] As a rule of thumb, he further reasoned, both averages and variabilities must be specified when one defines or distinguishes types.[41] Moreover, Boas conceived of types dynamically rather than statically. Throughout his career he was involved in the heredity/environment, or in Galton's terms, the "Nature-Nurture" controversy.[42] Although agreeing with Galton that both nature and nurture played roles in shaping human beings, Boas emphasized the role of the environment, whereas Galton did the opposite. Once Boas lamented that he was mistakenly characterized as an environmentalist.[43]

Extremely critical of the comparative methods used by evolutionary anthropologists, Boas did not entirely give up his preference for the "comparative science" that he developed in his youth.[44] But his comparison was of a different sort from that of the evolutionary anthropologist. Since the world was too complex to be studied in all its individual variety, Boas believed that the construction of types, or groups, was necessary even though such constructions were only tentative and somewhat subjective. Types for Boas became an intermediate scientific category, lacking ultimate reality but useful as the first stage in understanding individuals in relation to the whole: the anthropologist should compare each individual with a proper type and then relate that type to the whole. His method consisted of two parts. First, it is necessary "to determine how the physical development of a given individual compares with the average physical development of the group to which he belongs." Then "we must compare both their averages and variabilities" of the concerned groups. The typological groupings themselves could be made "from various points of view," such as race, religion, age, and sex.[45] Here we see ideas of analysis of variance in a primitive form.[46] Statistics became important because, in order to place individuals in groups and to compare groups, we need to know at least averages and variabilities.

Boas's Statistical Work

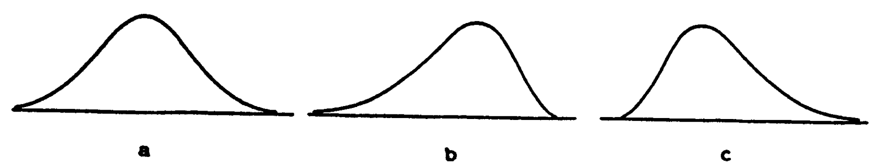
Having set out the intellectual background of Boas's ideas on statistics and types, it is time to proceed with a systematic treatment of his statistical work in the context of the anthropometrical studies that were popular in both Europe and America around the turn of the century. Over the years, Boas's interests shifted from the study of the growth of children to the problem of correlation, and later to the dispute over heredity, as his statistical skills matured.

1. The Growth of Children

Of particular concern to American physical anthropologists in the years 1891-1895 was the statistical study of the growth of children. "A study of the anthropology of children" wrote Boas, "is of the greatest importance for a knowledge of the conditions and laws of growth."[47] What first attracted his attention to the statistical side of this problem was the puzzling fact first observed by H. P. Bowditch and later confirmed by other investigators: statures and weights of children of a given age were found to be asymmetrically distributed, contrary to the conclu-

sions that would be drawn from Quetelet's model of the "average man." This anomaly posed a threat to the legitimacy of applying the law of error to anthropometry.[48] Like his contemporaries, Boas had assumed that the normal distribution was a fundamental mathematical law of nature. Indeed, he wanted to explain the peculiarities found in the raw data in terms of normal distributions.

Through a longitudinal study of school children, Boas reached his solution, which enjoyed a great success. He showed that the asymmetries could be explained in terms of normal curves once the variability in growth rate was taken into account. First, he classified children, depending upon their rate of growth, into what he called "development stages." Because the number of children in each stage was the result of "accidental causes," he argued, it could be assumed that children along the dimension of development were normally distributed. Furthermore, he assumed the statures (or weights) of children at any stage of development to be normally distributed. In other words, the distribution of children's statures (or weights) at a given age was seen as a combination of two normal distributions. If the growth rate is fixed, the overall curve remains symmetrical. When the growth rate is decreasing, however, the combined effect of the two normal distributions is to produce a negatively skewed curve. A similar argument can be made for the case of an increasing growth rate (see Figure 1). Therefore, by dividing a group of



a. rate of growth is constant.
b. rate of growth is decreasing with age.
c. rate of growth is increasing with age.

Figure 1

children of a certain age into subgroups, or developmental stages, Boas was able to show that the asymmetry of the distribution of their statures (or weights) was caused by the changing rate of growth, while normal distributions still held for the distribution of developmental stages and the distribution of statures (or weights) within each stage.[49]

In another article, Boas objected to the common practice of "a comparison of averages and of the frequency of occurrence of cases between certain limits" on the ground that such a practice assumed homogeneity of the children of different ages and ignored the effect of mortality. Boas reasoned that, because younger children had a greater chance of dying before maturity, the classification of children according to age is necessary, and "the classes . . . will be differently constituted."[50]

As we have observed, Boas's classes, or types, could be obtained by classification in any meaningful way. In the study of the growth of children, he attempted various groupings and felt justified when such a grouping shed new lights on the problem.[51]

2. The Problem of Correlation

If Bowditch's asymmetrical curve introduced Boas to the problem of distribution, W. T. Porter's misuse of the concept of correlation stimulated Boas's interest in the problem of the covariation of two variables. In 1893 Porter claimed, based on his observation of the correlation between children's physical growth and mental growth, that physical growth was the underlying cause for mental growth.[52] This conclusion irritated Boas, who rejected Porter's naivety in equating correlation with causation:

> The interesting facts presented by Dr. Porter prove only that children of the same age who are found in higher grades are more advanced in their general development than those who are found in lower grades. Dr. Porter has shown that mental and physical growth are *correlated, or depend upon common causes*; not that mental development depends upon physical growth.[53]

It is evident from this passage that Boas had embraced an interpretation of Galton's correlation similar to that of Karl Pearson, whose philosophy of science had questioned the traditional conception of scientific laws as indicative of causations and proposed correlations as an alternative. Correlation was "a category broader than causation," Pearson argued, and "formerly the quantitative scientist could only think in terms of causations, now he can think also in terms of correlation."[54] To both Boas and Pearson, causation was a special case of correlation, and mere correlation was not necessarily indicative of causation.

Pearson had scorned Porter as a "dilettante statistician" who had an "absolutely erroneous" theory of correlation and was delighted with

Boas's criticism of Porter's work, which would "show Mr. Porter that I [Pearson] was not alone in criticizing his methods."[55] What upset Pearson most was the fact that it became common for incompetent investigators to collect data "with no real insight into the theory." Thus, he urged, as did Boas for anthropology, the professionalization of statistics. Statistics, Pearson insisted, "must be taken out of the hands of the dilettanti" and given to the hands of those with "credentials in the form of a fair mathematical training."[56] Boas certainly had such "credentials." With his Ph.D. in physics, Boas was mathematically qualified and was destined to dabble on the frontiers of statistics.

In fact, Boas's own interpretation of correlation was first expressed as early as in 1894, in a paper entitled "The Correlation of Anatomical or Physiological Measurements." There Boas demonstrated how well he understood Galton. Just as Galton attributed correlation to "the variations of the two organs being partly due to common causes,"[57] Boas stated that two variables M and M_1 are correlated when they are influenced by common factors:

> The variable conditions. . .may be divided into three classes: those which influence M alone, which we will call x; those which influence M_1 alone, which we will call y; and those which influence both M and M_1, which we call z.
>
> $$M = f(x_1, x_2, \ldots x_m; z_1, z_2, \ldots z_p)$$
> $$M_1 = f(y_1, y_2, \ldots y_n; z_1, z_2, \ldots z_p)$$
>
> When the influence of z disappears in those functions M is independent of M_1, [and the more influence of z, the stronger the correlation between the two variables].[58]

It is evident that, for Boas, the relationship between two correlated variables is strictly symmetrical. There was no distinction between dependent variables and explanatory variables. Thus Boas equated the relative effect of the common causes with the degree of correlation, and he found two ways to measure it. First, in following Galton, Boas grouped individuals by average value of one variable M_1 and looked for a trend in the group averages of the other variable M. In this way he could draw line L_1, the regression line of M on M_1. Originally, Galton called this phenomenon "regression" or "reversion" because the second variable M varies less extremely than the first variable M_1 and therefore "regresses" toward its mean.[59] Boas reasoned that, if two variables M and M_1 are partly due to common causes, it was possible to regress M_1 on M and M on M_1 in the same graph, represented by L and L_1 respectively.

Then the degree of correlation was made explicit: the closer the two lines, the stronger the correlation between the two variables. This method was largely based on comparisons of group averages. Boas's concern with variability led him to consider another measure of correlation:

> Whenever individuals showing a certain value of a measurement are grouped together, the variability of any second measurement of the group is smaller than the variability of the whole series. . . .We may consider *the amount of the decrease in variability a supplementary measure of. . . .the amount of correlation between the two measurements.*[60]

Here Boas was actually using the reduction of variance as the indicator of the degree of correlation, an idea akin to analysis of variance, a method now widely used in statistics. To Boas, if breaking down the whole into groups resulted in more precision and less variabilities, it meant further closeness to the truth and thus was the proper method.

The interlude 1895-1897 marked an important transition in Boas's statistical work, namely his assimilation and improvement of Pearson's techniques that were published in a series of papers on regression and heredity.[61] Boas was deeply impressed by Pearson's contributions and acknowledged that the problems of correlation "were first discussed by Francis Galton, but the method of treatment has been fully developed by Karl Pearson."[62] Nevertheless, Boas did not overestimate Pearson's method, which was "still in its infancy" and could not be used for distinguishing types. "Biological assumptions" were necessary.[63]

Despite its limitations, Boas still preferred a statistical description of racial types for its advantage of "giving greater accuracy to the vague verbal description." One of the criteria which could be measured statistically and which "by experience have been found to be useful" was the cephalic index, or "the proportion of width to length of head."[64]

The 1899 paper "The Cephalic Index," which Boas himself proudly called "a simple proof of Pearson's methods,"[65] was an important landmark in the development of Boas's statistics. There Boas for the first time presented equations for more than two variables. A simple correlation coefficient was shown to be composed of a number of terms determined by partial correlation coefficients:

$$R_{12} = R_{123\ldots p} + R_{132\ldots p}R_{32} + \ldots + R_{1p2\ldots(p-1)}R_{p2}$$

$$R_{13} = R_{123\ldots p}R_{23} + R_{132\ldots p} + \ldots + R_{1p2\ldots(p-1)}R_{p3}$$

. . .

. . .

$$R_{1p} = R_{123\ldots p}R_{2p} + R_{132\ldots p}R_{3p} + \ldots + R_{1p2\ldots(p-1)}$$

where R_{ij} is the simple correlation coefficient between X_i and X_j, and $R_{1i2\ldots p}$ is the partial correlation coefficient between X_1 and X_i controlling for all other variables. The simple correlation coefficient R_{12}, for example, was shown to be related to all other variables, and only R_{12}, for example, was shown to be related to all other variables, and only $R_{123\ldots p}$ is the pure correlation. This sounds like today's path analysis and structural equations, only without any assumption about causal directions. By this method, Boas was able to show the "spuriousness" of the correlation between length and breadth of head, as both were affected by head capacity:

> The correlation between length and breadth is not an expression of a biological relation between the two measurements, but an effect of the changes which both undergo when the capacity of the skull increases or decreases. The cephalic index, therefore, is not the expression of a law of direct relation between length and breadth of the skull.[66]

Boas did not merely remain at the level of decomposition of correlations; he also justified his above finding by what was more characteristic of his work—analysis of variabilities.

According to Boas's definition, "the variability of each array is equal to the mean square of the differences between the members of the array and their average." Expressed mathematically, the variability of the array was written as

$$\Sigma(x_n - q_{n1}x_1)^2$$

where x_n is the observed value, and $q_{n1}x_1$ is the average predicted by the regression equation of x_n on x_1. Then Boas went on[67]

$$\Sigma(x_n - q_{n1}x_1)^2 = \Sigma x^2_n + \Sigma(q_{n1}x_1)^2 - 2\Sigma q_{n1}x_nx_1 =$$

$$\Sigma x^2_n - \Sigma(q_{n1}x_1)^2$$

In modern language, Boas had observed that

$$SSE = SST - SSR$$

where SSE stands for the sum of squares of error, SST for the sum of squares of total, and SSR for the sum of squares of regression. This equation shows that the variability within groups is the portion of total variability not explained by the linear regression equation. Boas also extended the reasoning to the multiple regression case and made use of the reduction of variability as a measure of the explanatory power of a regression equation.[68]

3. Heredity

Boas was interested in the problem of heredity all his life. As early as 1893, he suggested that heredity might be the constant cause for deviations of certain anthropometrical data from the "law of error." And he proposed the theory of alternating inheritance, namely, that statistically one parent has dominant influence on some children and the other parent has dominant influence on other children. If alternating inheritance, rather than Galton's hypothesis of intermediate inheritance, was true, Boas argued, then the resulting distribution among offspring of mixed parentage would not be a normal distribution.[69] In 1899, Boas obtained new evidence: the correlation between length and breadth of head in Paris had been found very low, which Boas believed was due to "the effect of mixture of types upon the coefficient of correlation between length and breadth of the head." Only when mixture produced alternating types, Boas further inferred from his algebra, could mixture of types affect the correlation coefficient so significantly. Therefore, Boas concluded that the evidence was in favor of his alternating inheritance theory.[70]

Mendel's work was rediscovered in 1900, and his theory in some aspects coincided with Boas's hypothesis. It was no surprise that Boas incorporated Mendel's theory into his anthropometrical studies shortly after the turn of the century. Boas's 1903 paper began with the sentence: "The recent discussion of Mendel's law has called renewed attention to the phenomena of heredity." Then he went on criticizing the approach of Galton and Pearson. Particularly, Boas questioned their assumption that each parent had the same influence on each offspring in all cases. His own theory argued for alternating dominance of different parents. Moreover, if the assumption of equal influence does not hold, Boas argued, the variability of the offspring is related to the form of the parents in such a way that "the greater the difference between the parents, the greater must be the variability of the offspring."[71]

Boas had two methods to confirm his theory of alternating inheritance. The first was to compare directly parents' head forms with their children's by grouping and averaging. The results were not conclusive. Then he used the other method, that is, to "study the relation between the variability of children and the differences between the parental couples."[72] He grouped his data according to parental difference and compared variabilities in children's head form so arranged and arrived at a result in support of his hypothesis—the variability increased as the parental difference increased, with the correlation coefficient of the two being 0.67.[73]

Therefore, into the notorious Biometrician-Mendelian debate around the problem of heredity, Boas came along as the third contender.[74] Actually, his position was between the other two. Methodologically, Boas was on the Biometrician's side and believed that the ultimate test of Mendel's law should be statistical, not experimental.[75] But Boas's own theory was close to Mendel's law, that is, "the dominant influence of one parent or the other" rather than Galton's midparent hypothesis. In supporting his theory, Boas considered only the influence of immediate parents. This annoyed Pearson. With some appreciation of Boas's work, his rejoinder reads:

> Quite recently Dr. Franz Boas has published a very suggestive paper on "Heredity in Head Form." He proposed a theory that the cephalic index in man is a case of alternative inheritance, and that the offspring take after one or other parent. His theory is less general than my theory of 1899, because he excludes from consideration the reversion to grandparents or higher ancestry. It is more general than mine, in that he assumes imperfect and not perfect correlation between the groups of offspring and the individual parents whom they respectively follow. This I consider a distinct gain. But the neglect of ancestry, other than the immediate parents, renders the application of his theory to so-called Mendelian phenomena absolutely impossible.[76]

To explain the discrepancy of the conclusions reached by Boas and himself, Pearson also pointed out several technical mistakes in Boas's paper.[77]

Boas took Pearson's criticisms silently and developed his theory of alternating inheritance with new data in 1907. This time, while still holding the same conclusion, Boas conceded to Pearson by considering the effect of remote ancestors and using the phrase "reversion" instead of "influence."[78]

In 1908, Boas was asked by the United States Immigration Commission to investigate the physical characteristics of immigrants. The results showed that the bodily form of the immigrants had undergone a substantial change. Boas was convinced by the evidence that there was definitely "a great plasticity of human types."[79] This conclusion was, and even still is, widely misunderstood as "environment-determinist." Actually, Boas was ambiguous on the issue which of the two factors, heredity or environment, was more important in determining human types. There are two levels of types, Boas argued, "genetic types" that are "determined by heredity alone," and "physiological types" that are determined not only by "environmental conditions" but also by "the organism itself." In other words, the same genetic type can have different manifestations in different environments. The changes Boas found that the immigrants had undergone were "due to a physiological modification," and "there is nothing to indicate that these changes are in any sense genetic changes."[80]

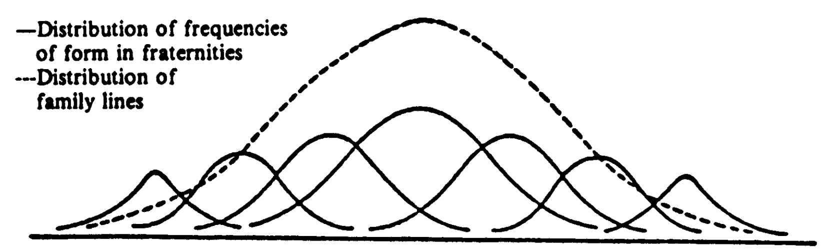
From the year 1916 on, Boas began to use "family lines" as the basic unit that carries heredity. He began with the measurement of the degree of inbreeding in a population. In the case of absolute inbreeding, Boas postulated, there would be no family resemblance whatsoever; in the case of absolute non-inbreeding, each family represents a particular type. Therefore, "strong family resemblances in a population are indications of the heterogeneity of the composite lines of descent."[81] Twelve years later, Boas formally wrote the formula

$$\sigma^2 = \sigma^2_l + \sigma^2_{fr}$$

where σ^2 stands for total variability, σ^2_l for between-family variability, and σ^2_{fr} for within-family variability. In words, the variability of a population was decomposed into two parts, the variability of family averages and that within families (fraternities).[82] Boas had been concerned with the problem of partitioning variance for more than thirty-five years and expressed the idea in various contexts. His central idea was that dividing a population into meaningful types would reduce the variability into smaller parts. Boas explicitly stated his method as follows:

> Our detailed study of the class will always be directed toward the discovery of new principles of classification by means of which subclasses are formed whose variability will be less than that of the original class. In this way we try to define the newly formed subclasses more sharply than the original class, and the advance in our knowledge consists in the discovery of the factors that make the subclasses more determinate.[83]

Less variability always meant to Boas more cleavage to the truth. Therefore, the rationale behind his insistence upon using types is self-evident: applying types will yield a more accurate description of both averages of types and the variances within individual types. Boas put this idea into a graph in 1938 (Figure 2).[84]



Distribution of frequencies of form in fraternities, and distribution of family lines.

Figure 2

Boas's statistical thinking, with its emphasis upon variability and types, is also reflected in his general anthropological writings. For example, his liberal views on racial issues were supported by his statistical reasoning. We should be reminded that Boas lived in an era when it could be said that "no rational man, cognisant of the facts, believes that the average negro is the equal, still less the superior, of the average white man."[85] Indeed Boas could not deny such "average differences" between races. It was his particular interest in "variability" that lent support to his anti-racist beliefs: the variability within each race is so great that the small average differences between distinct racial types are of minimum significance as compared to the total range of racial variability.[86] Here Boas was actually comparing average differences with within-group variabilities and came to the conclusion that the former was trivial as compared to the latter. This method was not original with Boas. Galton had compared distributions of intelligence among races and concluded that there was "a difference of not less than two grades between the black and white races" out of total sixteen grades within each race.[87] Therefore, both Boas's anti-racism and Galton's racism were bolstered by the same method, i.e., the comparison of differences in average with within-group variances.

Conclusion

Boas was not successful in persuading other anthropologists to apply quantitative methods to anthropology.[88] He was simply isolated. Most anthropologists of his day were suspicious of quantitative methods. Hrdlicka, for example, sarcastically referred to a scholar using statistics as "the lofty, disdainful 'biometrician,'" and asserted that "the tasks of the anthropologist therefore will always be essentially analytic—and analytic in the physiological rather than in the purely mathematical way."[89] The public, however, was less polite than Hrdlicka. Even when he was at Clark University (1889-1892), Boas was scorned by *The Worcester Telegram* as "the 'professor' of German birth and education whose face was marred by a cruel mensur scar, and declared falsely that the children would have to be undressed for some of the measurements."[90] Boas was, however, an undaunted fighter. He insisted that training in statistics be necessary for an anthropologist and put all of his new graduate students into his heavily mathematics-laden statistics course, which had to be taken at least twice to be understood.[91] Through his efforts, Boas could proudly claim that anthropology was more advanced than zoology in terms of statistical applications:

> Slight differences in type have been of importance to the student of anthropology at an earlier time than the student of zoology, because we are more deeply interested in the slight differences that occur in our own species than in those found among animals. . . . Anthropology was the first of the biological sciences to substitute measurement for description and the exact number for the vague word.[92]

Pearson certainly agreed with Boas on the effort to persuade anthropologists to give up their "rusty weapons" and to pick up the tool of statistics. He stated that "the most fertile training for academic purposes in anthropology is that which starts from anthropometry in its broadest sense." Like Boas, Pearson wanted to see a full recognition of anthropology, and believed that the only way to that end was to "give anthropology a technique as accurate as that of physics."[93]

Although Boas was a brilliant amateur statistician, Pearson did not like Boas to step into his own field. Pearson was polite enough to return a postcard inviting Boas to send a paper (which Boas did not) to his *Biometrika* after Boas wrote to him about some ideas on the method of moments which Boas thought were original.[94] But Pearson felt that his priority was threatened when Boas published a short article "Determina-

tion of the Coefficient of Correlation," and hastened to announce that Boas's three formulas were either "a very old friend" or a mistaken modification of formulas developed by Pearson himself.[95] Boas fought back in 1921 to defend his views on, rather than his formulas of, the coefficient of correlation, which had also been criticized by Pearson and other statisticians.[96]

Boas was only a good "applied" statistician. He did not develop his own system. His statistics suffered from his stubborn reluctance to make assumptions and his unswerving adherence to raw data.[97] With the rise of his fame as the founder of American anthropology in his late years, Boas gradually withdrew from statistical work. Nevertheless, the statistical spirit in his writings did not subside accordingly. Instead, he used more and more statistical arguments to support his views on issues about race, heredity, and eugenics.[98] By using the concept of types and considering the importance of variabilities, in addition to averages, Boas was able to escape from abstract mathematical reasoning while effectively dealing with raw data. His awareness of types and of variability enabled him to apply his unsystematic but consistent statistics to anthropology and to gain knowledge of the physical constructs of different races, but at the same time imprisoned him at the level of amateur statisticians.

Nevertheless, the present paper shows that statistics was central to Boas's thinking as a pioneering anthropologist. Intellectually, his concern with statistical variability was closely related to his conceptualization of anthropological problems regarding race and human types. Professionally, his emphasis on statistical methods was part of his program of upgrading American anthropology to the status of a science, on a par with the physical sciences. It is interesting to note that for many years Boas's statistical work has largely been ignored by historians and practicing anthropologists alike, while his work in cultural anthropology remains influential. This reflects in part the established status of anthropology as a science on the one hand, and on the other hand the accepted concern in today's social sciences of studying variabilities rather than averages. In Boas's day, he needed to persuade his contemporaries on both of these two counts. For his purposes, statistics proved to be a powerful tool.

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[1]Marshall Hyatt, *The Emergence of a Discipline: Franz Boas and the Study of Man*, diss., University of Delaware (1979), 335. Franz Boas (1858-1942) was born and educated in Germany, studying physics, psychophysics, and geography at the University of Kiel. After serving on expeditions to the Arctic and British Columbia, he settled in the United States in 1887. He joined the faculty of Columbia University in 1896 and remained there until his retirement in 1936.

[2]George W. Stocking, Jr., *Race, Culture, and Evolution: Essays in the History of Anthropology* (Chicago: University of Chicago Press, 1982); George W. Stocking, Jr., ed., *The Shaping of American Anthropology, 1883-1911: A Franz Boas Reader* (New York: Basic Books, 1974); Hyatt, *The Emergence of a Discipline*; Hamilton Cravens, *The Triumph of Evolution* (Philadelphia: University of Pennsylvania Press, 1978). Major memoirs of Boas are: Robert Lowie, "Franz Boas," Biographical Memoir, National Academy of Science 24 (1947), 303-80; Melville J. Herskovits, *Franz Boas* (New York: Scribner, 1953); A. L. Kroeber et. al., *Franz Boas, 1858-1942*, Memoir No. 61, American Anthropological Association (1943); and Walter R. Goldschmidt, ed., *The Anthropology of Franz Boas*, Memoir No. 89, American Anthropological Association (1959).

[3]Warren O. Hagstrom, *The Scientific Community* (New York: Basic Books, 1965), 159-254.

[4]Boas described his liberal views and belief in searching for truths in "An Anthropologist's Credo," *The Nation* 147 (1938), 201-4. For a critical review of literature on the "marginal man" and scientific innovations, see Thomas F. Gieryn and Richard F. Hirsh, "Marginality and Innovation in Science," *Social Studies of Science* 13 (1983), 87-106.

[5]Stocking, *Boas Reader*, 1-20.

[6]Boas, "The Study of Geography" (1887), reprinted in Boas, *Race, Language, and Culture* (New York: Macmillan, 1940), 645.

[7]Cravens, *The Triumph of Evolution*, 91.

[8]Boas to Mrs. Cornelius Stevenson, December 29, 1895, in Franz Boas, *The Professional Correspondence of Franz Boas*, microfilm, (Wilmington: Scholarly Resources, 1972).

[9]Ales Hrdlicka, "Physical Anthropology," *American Journal of Physical Anthropology* 1 (1918), 291.

[10]W. W. Howells, "Boas as Statistician," in Goldschmidt, ed., *Franz Boas*, 112. Helen M. Walker's *Studies in the History of Statistical Method* (Baltimore:

Williams & Wilkins, 1929) is probably the only book on the history of statistics where Boas's name is mentioned.

[11]Donald A. MacKenzie, *Statistics in Britain, 1865-1930: The Social Construction of Scientific Knowledge* (Edinburgh: Edinburgh University Press, 1981). For a history of eugenics, see Daniel J. Kevles, *In the Name of Eugenics* (Berkeley: University of California Press, 1985).

[12]Goldschmidt, "Anthropology and America," in Charles M. Bonjean et. al., ed., *Social Science in America* (Austin: University of Texas Press, 1976), 162-64.

[13]Boas, "The Study of Geography" (1887), reprinted in Boas, *Race, Language, and Culture*, 645.

[14]Boas, "Anthropology and Statistics," in William Fielding Ogburn and Alexander Goldenweiser, ed., *The Social Sciences and their Interrelations* (Boston: Houghton Mifflin, 1927), 114.

[15]Boas, *Anthropology and Modern Life* (New York: Norton, 1928), 12.

[16]Boas, *The Measurement of Variable Quantities*, No. 5, Archives of Philosophy, Psychology and Scientific Methods (1906), 1.

[17]Boas, "Anthropology and Statistics," 114.

[18]As Lowie reports, Boas admired Galton and Pearson highly, visited Galton in England some time after 1888, and kept frequent correspondence with Pearson for some time. See Robert Lowie, "Franz Boas." Lowie also recalls that "Tylor's famous paper on the application of statistics to sociological problems certainly impressed Boas; for a while, he told me, it seemed as though everything could be solved by the methods there outlined" (305); also see Boas, "The History of Anthropology" (1904), reprinted in Stocking, ed., *Boas Reader*, 23-36 for Boas's appraisal of Galton and Pearson.

[19]Victor Hilts, "Characterizing the Statistical Revolution in the Social Sciences: The Initial Phase," unpublished. Also see Victor Hilts, *Statist and Statistician* (New York: Arno Press, 1981), and MacKenzie, *Statistics in Britain*.

[20]Lambert A. J. Quetelet, *A Treatise on Man and the Development of his Faculties* [1835], a facsimile reproduction of the English translation of 1842 (Gainesville, Florida: Scholar's Facsimiles and Reprints, 1969), 9.

[21]Quetelet, *A Treatise on Man*, 96.

[22]Quetelet, *A Treatise on Man*, 8.

[23]In Quetelet's words, "If the average man were completely determined, we might, as I have already observed, consider him as the type of perfection; and every thing differing from his proportions or condition, would constitute deformity and disease; every thing found dissimilar, not only as regarded proportion and form, but as exceeding the observed limits, would constitute a monstrosity" (*A Treatise on Man*, 99).

24Ernst Mayr, "Darwin and the Evolutionary Theory," in Betty J. Meggers, ed., *Evolution and Anthropology: A Centennial Appraisal* (Washington, D.C.: Anthropological Society of Washington, 1959), 1-10; Ernst Mayr, *Evolution and the Diversity of Life: Selected Essays* (Cambridge, MA: Belknap Press, 1976); and Ernst Mayr, *The Growth of Biological Thought* (Cambridge, MA: Belknap Press, 1982).

25Quoted by Henri V. Vallois, "Race," in *Anthropology Today: An Encyclopedic Inventory*, prepared under the chairmanship of A. L. Kroeber (Chicago: University of Chicago Press, 1953), 151. The concept of types was of great importance in the polygenism-monogenism debate; see Stocking, *Race, Culture, and Evolution*, and Herbert H. Odom, "Generalizations on Race in Nineteenth Century Physical Anthropology," *Isis* 58 (1967), 5-18.

26Paul Topinard, *Anthropology*, 4th ed., (London: Chapman and Hall, 1894), 446-47.

27Victor Hilts, "Statistics and Social Science," in Ronald N. Giere and Richard S. Westfall, eds., *Foundations of Scientific Method: The Nineteenth Century* (Bloomington: Indiana University Press, 1973), 221. Also see Hilts, *Statist and Statistician*, 272-502, Francis Galton, *Memoirs of my Life* (London: Methuen, 1908), and Karl Pearson, *The Life, Letters, and Labours of Francis Galton* (Cambridge: University Press, 1914-1930), 3 vols., for more details of Galton's life and work.

28Francis Galton, *Natural Inheritance* (London: Macmillan, 1889), 35-36.

29Galton, *Natural Inheritance*, 57-58.

30See Hilts, "Statistics and Social Science."

31Ernst Mayr, "Darwin and the Evolutionary Theory."

32Boas, "The Occurrence of Similar Inventions in Areas Widely Apart," *Science* 9 (1887), 485.

33See Kevles for Boas's critique of eugenics. For Boas's attitude toward Mendelism, see Kroeber, "Franz Boas, the Man," in Kroeber et. al., eds., *Franz Boas*, 7; and Boas, "Inventing a Great Race," *The New Republic* 9 (1917): 305-7.

34For Boas's discussion on theory building and data collecting, see Boas, "The Limitations of the Comparative Method of Anthropology," *Science*, n.s. 4 (1896), 901-8, and Boas, "Advances in Methods of Teaching," *Science*, n.s. 9 (1899), 93-96. Both are reprinted in Boas, *Race, Language, and Culture*.

35Stocking, *Race, Culture, and Evolution*, 167.

36Boas, "The History of Anthropology," 35.

37Using the relationship between eugenics and statistics as an example, MacKenzie argues that "eugenics did not merely motivate their [eugenicists'] statistical work but affected its content. The shape of the science they developed was partially determined by eugenic objectives" (*Statistics in Britain*, 12).

38Galton, *Natural Inheritance*, 24.

39Boas, "Heredity and Environment," *Jewish Social Studies* 1 (1939), 5.

40Boas, "The Anthropology of the North American Indian" (1894), reprinted in Stocking, *Boas Reader*, 193; Boas, *The Mind of Primitive Man*, rev. ed. (New York: Macmillan, 1938), 42.

41Boas, *The Mind of Primitive Man* (1938), 46.

42Boas, "Statistical Study of Anthropometry," *American Physical Education Review* 4 (1902), 178; Boas, "Some Recent Criticisms of Physical Anthropology," *American Anthropologist* 1 (1899), 100; also see Boas, "Heredity and Environment," and Boas, *The Mind of Primitive Man* (New York: Macmillan, 1921), 30-94.

43Boas once protested to his friend James McKeen Cattel for characterizing him as representative of environmentalism, because "he, too, attached very great importance to heredity" (Lowie, "Franz Boas," 316).

44Boas, "The Limitations of the Comparative Method of Anthropology" (1896), repr. in Boas, *Race, Language, and Culture*, 270-80; in a discussion on studying botany in his youth, Boas once wrote, "I learnt that true science does not consist in describing individual plants but in understanding their structure and life and in comparing all the different groups of plants with one another. . . . I had already discovered that I preferred comparative science to the descriptive" (quoted by Hyatt, *The Emergence of a Discipline*, 4).

45Boas, "Statistical Study of Anthropometry," 174; Boas, *The Mind of Primitive Man* (1938), 46; Boas, "Statistical Study of Anthropometry," 177.

46Analysis of variance is a popular technique in modern statistics. The basic principle is to decompose total variance into within-group variance and between-group variance. See, for example, Morris H. DeGroot, *Probability and Statistics* (Reading, MA:Addison-Wesley, 1975).

47Boas, "Anthropological Investigations in Schools," *Science* 17 (1891), 351. For a discussion on anthropometry and statistics in this period, see Hilts, "Characterizing the Statistical Revolution."

48For a fuller account of the background history and Boas's contribution to the problem, see J. M. Tanner, "Boas' Contributions to Knowledge of Human Growth and Form," in Goldschmidt, ed., *Franz Boas*, 67-116.

49Boas, "The Growth of Children," *Science* 19 (1892), 256-57.

50Boas, "The Growth of Children," *Science* 20 (1892), 351-52.

[51]As another example, Boas compared the first-born children and later-born children and was delighted with the result: "It appears from these four tables that first-born children exceed later-born children in stature as well as in weight. . . . We are, therefore, justified in grouping the measurements into two classes: first-born individuals and later-born individuals" (Boas, "The Growth of First-born Children," *Science*, n.s. 1 (1895), 403). The same rhetoric appeared in Boas's 1912 study comparing the process of maturity between boys and girls. Boas, "The Growth of Children," *Science* 36 (1912), 815-18.

[52]W. T. Porter, "The Physical Basis of Precocity and Dullness," *Transactions of the Academy of Science of St. Louis* 6 (1893), 161-81.

[53]Boas, "On Dr. Williams Townsend Porter's Investigation of the Growth of the School Children of St. Louis," *Science*, n.s. 1 (1895), 227; my emphasis.

[54]Quoted by Hilts, *Statist and Statistician*, 547, 565; for Pearson's philosophy of science, see Karl Pearson, *Grammar of Science* (London: Scott, 1892).

[55]Karl Pearson, "Dilettantism and Statistics," *Nature* 51 (1894), 145-46; Pearson to Boas, July 22, 1895, in *The Professional Correspondence of Franz Boas*.

[56]Pearson, "Dilettantism and Statistics," 145.

[57]Quoted by Pearson, "Notes on the History of Correlation" (1920), reprinted in E. S. Pearson and M. G. Kendall, eds., *Studies in the History of Statistics and Probability* (London: Griffin, 1970), 199.

[58]Boas, "The Correlation of Anatomical or Physiological Measurements," *American Anthropologist* 7 (1894), 313-21.

[59]See Galton, *Natural Inheritance*, 95-137.

[60]Boas, "The Correlation of Anatomical or Physiological Measurements," 320; emphasis mine.

[61]The Pearson papers that had influence on Boas are all collected in *Karl Pearson's Early Statistical Papers* (Cambridge: Cambridge University Press, 1956).

[62]Boas, "The Cephalic Index," *American Anthropologist*, n.s. 1 (1899), 450. In this period, Boas constantly referred to Pearson's name and had active correspondence with Pearson: three letters (July 22, 1895; May 20, 1897; November 22, 1897) are collected in *The Professional Correspondence of Franz Boas*.

[63]Boas, "A Precise Criterion of Species," *Science*, n.s. 7 (1898), 861.

[64]Boas, "Some Recent Criticisms of Physical Anthropology," *American Anthropology*, n.s. 1 (1899), 103.

[65]Boas to Joseph Jacobs, Oct. 27, 1903, in *The Professional Correspondence of Franz Boas*.

[66]Boas, "The Cephalic Index," 460.

[67]Boas, "The Cephalic Index," 452.

[68]"The variabilities of the arrays show that the *reduction of variability* of capacity is greatest. This proves that the four linear measurements which we have treated largely determine the capacity. The variability of the length and height of skull is very slightly reduced. This shows that these measurements are largely influenced by causes which we have not included in our considerations" (Boas, "The Cephalic Index," 461; my emphasis).

[69]Boas, "Remarks on the Theory of Anthropometry," *Quarterly Publications of the American Statistical Association* 3 (1893), 569-75.

[70]Boas, "The Cephalic Index," 453-55.

[71]Boas, "Heredity in Head Form," *American Anthropologist*, n.s. 3 (1903), 530.

[72]Boas, "Heredity in Head Form," 532.

[73]Boas, "Heredity in Head Form," 535-37.

[74]For a history of the Biometrician-Mendelian debate, see MacKenzie, *Statistics in Britain*, 120-52, and E. S. Pearson, *Karl Pearson, an Appreciation of some Aspects of his Life and Work* (Cambridge: Cambridge University Press, 1938), 34-50; Pearson made a comparison of the three theories in "On a Criterion which may Serve to Test Various Theories of Inheritance," *Zeitschrift für Morphologie und Anthropologie* 7 (1904), 524-42.

[75]Boas's "Heredity in Head Form" was a statistically substantiated paper; he also refuted the abuse of Mendelian theory by Madison Grant, an eugenicist, on the ground that Mendelian inheritance had not been proved by anthropometrical data, in "Inventing a Great Race."

[76]Pearson, "On a Criterion which may Serve to Test Various Theories of Inheritance," 525.

[77]Pearson, "On a Criterion which may Serve to Test Various Theories of Inheritance," 541.

[78]Boas, "Heredity in Anthropometric Traits," *American Anthropologist* 3 (1907), 453-69, where Boas wrote: "Our series justifies, therefore, the conclusion that the cephalic index shows alternating inheritance, largely reversion to the type of father and mother, but also to more remote ancestral types" (461).

[79]Boas, *Changes in Bodily Form of Descendants of Immigrants*, Senate Document 208, 61st Congress, (Washington, D.C., 1912), 5.

[80]Boas, "New Evidence in Regard to the Instability of Human Types," *Proceedings of the National Academy of Sciences* 12 (1916), 713-18.

[81]Boas, "On the Variety of Lines of Descent Represented in a Population," *American Anthropologist*, n.s. 18 (1916), 2.

[82]Boas, "Family Traits as Determined by Heredity and Environment," *Proceedings of the National Academy of Sciences* 6 (1928), 496-503.

[83]Boas, "The Measurement Differences Between Variable Quantities," *Journal of the American Statistical Association* 18 (1922), 427.

[84]Copied from Boas, "Race," in Boas, ed., *General Anthropology* (Boston: Heath, 1938), 101.

[85]T. H. Huxley, quoted by Stephen Jay Gould, *The Mismeasure of Man* (New York: Norton, 1981), 73.

[86]Boas, *Anthropology*, Columbia University Lectures on Science, Philosophy, and Art, no. 10 (New York, 1908), 14. Boas first used this argument in 1894 in his article "Human Faculty as Determined by Race," *Proceedings of the American Association for the Advancement of Science* 44 (1894); 301-27, repeated it in many places, and synthesized it his famous book *The Mind of Primitive Man* (1938).

[87]Galton, *Hereditary Genius*, 2d ed., (London: Macmillan 1914), 327.

[88]Of Boas's students, only Kroeber made use of quantitative methods in ethnology. See Amanda L. Golbeck, "Quantification in Ethnology and its Appearance in Regional Culture Trait Distribution Studies (1880 to 1939)," *Journal of the History of the Behavioral Sciences* 16 (1980), 228-40.

[89]Ales Hrdlicka, "Physical Anthropology," *American Journal of Physical Anthropology* 1 (1918), 15.

[90]Quoted by Hyatt, *The Emergence of a Discipline*, 54.

[91]Herskovits, *Franz Boas*, 23.

[92]Boas, "Advances in the Methods of Teaching" (1899), reprinted in Boas, *Race, Language, and Culture*, 623. Boas made a similar statement in "The History of Anthropology," 32.

[93]Pearson, "The Science of Man, its Needs and its Prospects," *Questions of the Day and the Fray*, no. 10, 16.

[94]Boas to Pearson, August 25, 1905, and Pearson to Boas, September 7, 1905, in *The Professional Correspondence of Franz Boas.*

[95]Boas, "Determination of the Coefficient of Correlation," *Science* 29 (1909), 823-24; Pearson, "Determination of the Coefficient of Correlation," *Science* 30 (1909), 23-25. For a sociological account of priority disputes, see Robert K. Merton, *The Sociology of Science: Theoretical and Empirical Investigation* (Chicago: University of Chicago Press, 1973), 281-412.

[96]Boas, "The Coefficient of Correlation," *Quarterly Publications of the American Statistical Association* 17 (1921), 683-88.

[97]See Boas, *The Measurements of Variable Quantities*, which was based on Boas's statistics lectures at Columbia.

[98]We mention only a few important works of Boas that contained no algebra but made good use of statistical arguments involving the concepts of types and of variabilities: *The Mind of Primitive Man*; "Report on an Anthropometric Investigation of the Population of the United States," *Journal of the American Statistical Association* 18 (1922), 181-209; *Anthropology and Modern Life*; and *Race and Democratic Society* (New York: Augustin, 1945).