REMARKS ON THE THEORY OF ANTHROPOMETRY.

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The theory of anthropometric statistics is based largely upon Quetelet's investigations, who endeavored to prove that the distribution of anthropometric data follows the law of chance. Some attempts to develop the theory further have been made by Stieda and Ihering and by Francis Galton. The former emphasized the introduction of the average variation of measurements into the consideration of the subject, the latter developed what has become known as the method of percentile grades. Stieda was also the first to express a doubt as to the general applicability of the law of chance.

The anthropometric characteristics of a group of people are treated in various ways. Some authors consider the average of the measurements the most valuable result; others prefer to compute the mean value, which is, more properly speaking, the probable value, as it is computed as that value above and below which fifty per cent of the whole series are found; still others compute the most frequent value. The followers of Francis Galton compute the mean value and the points representing various percentile grades, *i. e.*, points below which ten per cent, twenty per cent, thirty per cent, and so forth, of the total series are found. Anthropologists who study the physical characteristics of races use mostly the method of seriation. They give the percentage of cases of the series which fall between certain limits. Still another method which is frequently applied consists in the comparison of those percentages of the series which lie above or below a certain limit.

We will examine the merits of these methods. Whenever the distribution of measurements follows the laws of chance the average may be considered the type represented by the series. In this case the average, the probable value, and the most frequent value will be identical, provided the series of observations is sufficiently large. In practice they will naturally always show slight differences. In these cases the average must be used, not the probable or the most frequent value, because the first named can be determined with greater accuracy than the others. When a limited number of observations are given, and the mean error of the average, of the probable value, and of the most frequent value are computed, it is found that the mean error of the average is smaller than that of the probable value; the mean error of the latter is, in turn, smaller than that of the most frequent value. For this reason the probable value, or, as it is often called, the mean value, or the fifty percentile grade, must not be used for the purpose of describing the type of a series of measurements which are distributed according to the laws of chance.

When the distribution of cases does not correspond to the laws of chance, neither the average, nor the probable value, nor the most frequent value can be utilized without a previous theoretical treatment of the curve representing the laws of distribution. Based on Quetelet's statements, it has generally been assumed that all anthropometric measurements are distributed according to the laws of chance, and that the curves will approach the theoretical curve the more closely the greater the number of cases that is embodied in the series. I believe that Stieda was the first to intimate that deviations from the law may occur, although he does not follow out this suggestion. A. and J. Bertillon have proved that such deviations occur. Later on, Bowditch has shown that the curves showing the distribution of statures and weights of children do not follow the laws of chance. He shows this by pointing out the fact that during the period of growth a constant difference exists between the average and probable values. Galton also paid some attention to this subject, and Dr. Gulick mentioned it in a recent paper. Glancing over the curves representing large series of measurements, it strikes me that they conform to the laws of chance only in a general way, and that considerable deviations are quite frequent. It is necessary to consider the biological laws underlying the phenomena under consideration. Assuming that there is a uniform ancestral type in a certain district, and that the conditions of life remain stable, we may expect that the people representing its offspring will be grouped around the type according to the laws of chance. Assuming, however, that there were two distinct ancestral types in adjoining districts, and that these types intermingled, we cannot foretell what the distribution of forms among the offspring will be. It may be that they represent an intermediate type between the parental forms. In this case we might expect to find them distributed according to the laws of chance. But it may also be that we find them to have a tendency to reproduce one or the other ancestral type, either pure or slightly modified. In this case the resulting curve would not conform to the laws of chance, and would show an entirely different character. There is considerable evidence that the laws of inheritance are such that there exists a tendency of reproducing ancestral traits, not of producing new intermediate traits. Therefore, we may be prepared to find considerable deviations from the laws of chance. It is clear that, if intermixture does not result in producing an intermediate type, an attempt to express the type by means of an average of the existing forms will have no meaning whatever. The probable value would have just as little meaning. If the two parental forms were entirely distinct and reproduced without change, the most frequent values might have a meaning, as the two forms would occur most frequently. This, however, would depend upon many conditions favorable to such a result; the proportion of the two elements would have to be nearly equal, their difference great, and each form must have a limited amount of variability only. A concrete case of this kind is found in the anthropometry of the half-blood race of Indian and white parentage. Generally speaking, the ancestry of a people will be such that a number of forms which do not differ very much among themselves enter into its composition. The greater the number of forms, the nearer the curve of measurements will conform to a probability curve; but, nevertheless, it must be borne in mind that the mixture may be such that constant deviations from such a curve are found which are not due to accident. Our conclusion from these considerations is that anthropometric measurements do not, as a rule, follow the laws of chance, and that a careful examination of the curves is necessary in each case. We cannot expect that in all cases a classification of the material will lead to curves which follow the laws of chance more closely, as the laws of heredity are such that they do not necessitate an arrangement of this character. These facts must make us very careful in the use of the average considered as the type of a series. It will be necessary to investigate each series in order to ascertain if there are any deviations from the law of chance which seem to be due to constant causes, not to accident.

Besides these biological considerations, we must consider a number of other factors which may cause deviations from the probability curve. If a series of measurements is distributed according to the laws of chance, and the measurements of the whole series are changing, deviations will occur whenever the rate of change is not uniform. Such changes occur during the period of growth, and this is the cause of the asymmetry of distribution of measurements of children to which Dr. Bowditch called attention. Similar changes may occur when the conditions of life of a community are changing, or when one form is gaining preponderance over another form. In all such cases the computation of the average, of the mean, and of the most frequent value have no meaning. The cause and character of the asymmetry of the curve must be determined, and a mathematical treatment must be applied which takes the asymmetry into consideration. It is not necessary to elaborate the theory of treatment of such curves, as the treatment depends upon the character of the asymmetry. It will be sufficient to say that during a period of acceleration in the increase of the measurement the average will always be too great as compared to the typical value for the period under consideration, while for a period of retardation in the increase of the measurement the reverse is the case. For this reason the values for average statures at a certain age which have been computed so often have no biological value as typical statures for the respective age.

I believe I have shown that we must exercise great care in the application of the method of averages, particularly that we cannot assume the average to be the type of a series without a careful scrutiny of its character.

This is still more true if we consider correlations of measurements. It is generally assumed that when a group of measurements of a series of individuals is taken the combination of the average of the measurements will represent the typical individual. Dr. Sargent's statues of the typical American are based on this assumption. The first objection to this assumption is based on the well-known fact that, if a variable is given and a function of the same, then the average of the function is not identical with the function of the average of the variable.

Furthermore, the general distribution of the measurement may apparently correspond to the law of chance, although a number of distinct types are represented in the series whose presence may be revealed by a classification of the whole series. For example: If the measurements of the Indians around the Great Lakes were tabulated without a subdivision into tribes, it would be found that their length of head and breadth of head are distributed according to the laws of chance. The average length of head would be 193 mm., the average breadth of head 155 mm. According to the method under consideration, this would be the typical combination. When the tribes are properly subdivided in an eastern and a western group, it will be found that the length of head is 195 mm. in the west, 191 in the east, and that 193 does not represent the type of any one tribe. These people speak the same language, and might be gathered on one reservation. In that case a subdivision would be impossible, and an erroneous result would be obtained. Therefore, a critical study of distributions must precede the establishment of the type. The theory of statistics points to a clear way for this study, but unfortunately it has never been applied up to this time. The study must be based on a comparison of the variabilities of measurements. Whenever the variability of a measurement that is correlated to another one is abnormally increased we must suppose that there is an intermixture of types.

I must add a few words regarding the subject of correlations.

The admirable investigations of Mr. Alphonse Bertillon and those of Sören-Hansen, Bischoff, and others have proved that with increasing height all other measurements increase not proportionally, but at a slower rate. This law may be given a wider meaning by saying that whenever a group of people are arranged according to one measurement, with the increase of this measurement all others increase at a slower rate, the rate being the slower the slighter the correlation. This law leads us to establish the fact that we must consider each measurement as a function of a number of variable factors which represent the laws of heredity and environment. The correlation of two measurements will be close when they depend largely upon the same factor, slight when they depend largely upon distinct factors. This difference in the degree of correlation, which is a well-established fact, proves that the system which is applied in many of our gymnasia is faulty. If the teacher of the gymnasium is given a pupil whose stature is, for instance, such that twenty per cent of all the individuals of his age are taller than he, then it is his ideal to train the pupil to that point that all his other measurements come up to the same standard. If all the men who have this particular stature were plotted alone, it would be seen at once that their measurements would be quite different from this assumed standard. This fundamental objection has already been raised by Dr. L. Gulick.

This assumption is one of the developments of the method of percentile grades. While this method has certain advantages in bringing home to the untrained public some of the valuable results to be gained from anthropometric inquiries, it is highly objectionable for theoretical studies. It does not explain any fact that cannot be explained just as well and with the tenth part of labor and with greater satisfaction by the method of mean variations, and whenever it has been applied it has proved to be misleading in so far as it suggests always that a certain percentile grade represents certain groups of individuals. For instance, during the period of growth, the average eighty per cent child has been assumed to represent, "on the average," the same child, which is most assuredly not the case. This method ought, therefore, to be applied with much greater care and for much more limited purposes than has been done heretofore.

I hope my remarks have served to point out some of the directions in which the theory of anthropometric statistics needs further treatment, and what defects remain to be remedied. I have in my full paper given a number of examples and elaborated the theories and methods which here I could indicate only with a few words.