BIOMETRICAL STUDIES ON MAN.

I. VARIATION AND CORRELATION IN BRAIN-WEIGHT*.

By RAYMOND PEARL, Ph.D.

CONTENTS.

	PAGE
1. Introduction	13
2. Data	16
3. Fundamental Constants	21
4. Brain-weight Types	22
5. {Variation in Brain-weight	29
{Homogeneity of Material	29
6. On the Nature of the Frequency Distributions	37
7. The Correlation of Brain-weight with other Characters	42
8. Brain-weight and Sex	45
9. Brain-weight, Age and Stature	51
10. Brain-weight and Body-weight	64
11. Brain-weight and Skull Characters	67
12. The Weight of the Cerebrum	74
13. Concluding Remarks	76
14. Summary	82
Appendix. Correlation Tables	83-104

1. *Introduction.*

THE subject of brain-weight in man has for a long time been given considerable attention by anatomists and anthropologists. The reason for this is obvious. Since the brain is the organ of the mind it appeared to earlier workers that size of brain ought to be an index of intellectual capacity. The substance of the brain is of such physical homogeneity that its weight is a fairly accurate, as well as simple, "size" measure of the organ. Consequently, by earlier workers, brain-weights were collected, studied and discussed to a considerable extent as measures

* Contributions from the Zoological Laboratory of the University of Michigan. No. 86.

or indices of brain power. It became evident after a time, however, that there was not the close and definite relationship between brain-weight and intellectual capacity which had been supposed to exist. Individuals of marked intellectual power were found in not a few instances to have brain-weights below the average, while on the other hand it was not at all difficult to find individuals of very mediocre intellectual attainment who possessed brains of unusually large size and weight. These results still held even after rough corrections were made for bodily size, age, etc. While it is thus evident that brain-weight cannot be taken as a close index of intellectual power, holding for individual instances, yet it is clear that, considered from the phylogenetic standpoint, increase in brain-weight and in psychic capacity have in general gone hand in hand, and the weight of the brain increases quite regularly as we go up the taxonomic scale*.

The present trend of investigation in this subject, is rather from the point of view of anthropology than of psychology. Evidently brain-weight is an important and interesting anthropological character, and in this field we may expect significant results.

The method of investigation which has been almost universally followed in brain-weight work has been to tabulate large masses of statistics of weighings, compute means for various groupings, and draw the conclusions which appeared to follow from the tabulations and averages. In other words the only statistical methods which in most cases have been applied to the data have been those of the sociological statistician. Such methods serve fairly well, of course, when only the "types" are wanted, but they are quite inadequate for some of the work which many neurologists have wished to do in this field. Practically all students of the subject have attempted to determine in one way or another the degree of correlation which exists between brain-weight and other physical characters and also age. Knowledge of these correlations is of course much to be desired. The human brain is justly to be regarded as the highest product of organic evolution. Any contribution to a knowledge of the laws governing its variation and correlation cannot fail to be of the greatest interest. Again, only through a knowledge of the degree of the correlation of brain-weight with other characters of the body is it possible to make scientifically such suitable corrections for bodily differences as will make fair any comparison of the brain-weights of different races, or of different groups of the same race. Now, as everyone knows who has even an elementary knowledge of statistics, it is possible to make the same statistical material lead to quite different conclusions, by grouping it in different ways, when the tabulations and averages are the only sources from which conclusions may be drawn. As a matter of fact this has happened in work on brain-weights. Different investigators, working in different ways, have arrived at

* Cf. Ziehen, Th.: "Das Gehirn, Massverhältnisse," *Bardeleben's Handbuch der Anatomie des Menschen*, Bd. iv. 1—3 Abtheilung, pp. 353—386, 1899, p. 362 et seq.; and more recently Spitzka, E. A.: "Brain-weight of Animals with special reference to the Weight of the Brain in the Macaque Monkey," *Jour. Comp. Neurol.* Vol. xiii. pp. 9—17, 1903.

quite different numerical appreciations of the relation existing between brain-weight and other characters. The very interesting question of variation in brain-weight has been scientifically investigated only by Pearson*, so far as is known to the writer.

The reason which led me to undertake the present piece of work was primarily a desire to apply adequate statistical methods to a biometrical problem of peculiar intrinsic interest, and for which fairly large collections of reliable data were available. It was desired to determine as a part of a general plan of work outlined as exactly as possible from the data at hand, what were the actual conditions of variation and correlation in brain-weight. It was hoped that by such work some light might be thrown on the question of the evolution of man's brain. The work was originally planned to include the analysis of only one large collection of brain-weight data (see below p. 16) but when the constants for this material had been determined certain of the results were seen to be rather peculiar. Not being satisfied that these indicated the true state of affairs, but thinking that they might be caused by some hidden anomalies of the raw material, it was decided to extend the work to other data in order to test the first results.

The specific problems to which attention has been directed in this work are:

1. The amount of variation in the weight of adult male and female brains.
2. The relation of brain-weight to age in the adult.
3. The relation of brain-weight to stature and body-weight in the adult.
4. The relation of brain-weight to skull characters.
5. The nature of the regression of brain-weight on these other characters.
6. The effect of natural selection on brain-weight.
7. The value of brain-weight statistics from the anthropological standpoint.

At this point I wish to acknowledge my indebtedness and express my thanks to the officials of the Carnegie Institution for a grant through which I obtained a large Brunsviga arithmometer and other necessary apparatus for statistical work. This aid enabled me to extend this work far beyond what would have been possible had I been restricted to "long-hand" methods of computation. The amount of arithmetical calculation necessary in any extensive biometrical investigation is so great that it may almost be said that such work cannot profitably be undertaken on any large scale unless one has at command the various mechanical aids which reduce to a minimum the time necessary to carry out the computations. To my wife I am especially indebted for much aid in the computing, and for the diagrams which accompany the paper. To Prof. H. H. Donaldson I am indebted for the loan of some unique and valuable manuscript records of brain-weighings, as well as for numerous helpful suggestions regarding the work as a whole.

* Pearson, K.: "Variation in Man and Woman," *The Chances of Death*, Vol. 1. pp. 319—323.

2. *Data.*

The statistical data for this study were obtained from several sources, as has been mentioned above. The work was begun on Marchand's statistics, then extended to include the old, but still valuable collection of brain-weights by Bischoff. With the results from these two series in hand, I was still not satisfied that I had analyzed sufficient material to be certain of the conclusions. So I determined to include the following material in the discussion: (1) the admirable series of brain-weights of Swedes collected by Retzius. (2) Matiegka's Bohemian series. (3) The Boyd-Marshall data observed at the St Marylebone Infirmary. As will appear later the last mentioned series was used only for a special purpose. The general results of this paper are based on the analysis of the Marchand, Bischoff, Retzius and Matiegka series.

Marchand's* data were obtained from a series of brain-weighings made between the years 1885-1900 in the Pathological Institute at Marburg. The total number of brains weighed was 1234. Of this number 389 were from individuals under 15 years of age, and hence were unavailable for adult brain-weight studies. The data recorded from each individual in Marchand's work included, in addition to brain-weight, sex, age, and stature. It was not possible, however, to determine all of these points in every case, so that omissions of one or more records for an individual occur not infrequently in these statistics. The same is of course true of all extensive series of brain-weight data ever collected. After all such incomplete records have been thrown out there remain in Marchand's tables 475 male and 281 female complete records, or a total of 756 of both sexes. Marchand did not include body-weight in his determination, because he considered that: "das Körpergewicht bei dem Leichenmaterial der Krankenhäuser ein so wechselnder Faktor ist, dass bestimmte Beziehungen zum Gehirngewichte sich daraus kaum ableiten lassen würden."

The brains were weighed in the fresh condition, usually immediately after removal from the cranial cavity. The membranes were not removed before weighing. The weighings were made in the majority of cases to the nearest 5 grams, greater accuracy not being possible on account of such unavoidable sources of error as varying amounts of blood in the vessels of the brain, amount of fluid in the ventricles and membranes, etc. These sources of error cause variations in the total weight outside the limits of 5 grams. Marchand's material comes from the "hessische Bevölkerung."

Bischoff's† data comprise the results of the weighing of something over 800 brains of individuals between the ages of 17 and 85. The attempt was to determine for each individual the following characters in addition to brain-weight: sex, age, cause of death, stature and body-weight. Omissions in the records were

* Marchand, F.: "Ueber das Hirngewicht des Menschen," *Abhandl. d. math.-phys. Cl. d. Königl. Sachs. Gesellsch. d. Wiss.* Bd. xxvii. No. iv. pp. 393-482, 1902.

† Bischoff, T. L. W. v.: *Das Hirngewicht des Menschen*, Bonn, 1880, Pp. vi. and 171, plus Tables.

fairly numerous, so it was only possible to extract full data on sex, stature, body-weight and brain-weight for 365 males and 241 females. This material I have referred to in this paper as the "short" Bavarian series. For determining the correlation between brain-weight and age I was able to extract 529 male and 323 female records from Bischoff's tables. This larger group I have called the "long" Bavarian series. The brains were weighed in the fresh condition, soon after removal and with the membranes. Nearly all the individuals had died in hospitals and a considerable number of them were convicts. Practically all were members of the middle and lower classes of society. The causes of death for this and Marchand's series were very varied, including a wide range of diseases and accidents, so that the material is not vitiated by the great preponderance of some one cause of death which might have a specific effect on brain-weight. The great majority of the individuals included in Bischoff's series were Bavarians.

The Swedish data used were collected by Retzius*. The source of the material was in the main the autopsies at the great Sabbatsberg Krankenhaus in Stockholm, although some of the returns were from autopsies at the Maria Krankenhaus. This series of brain-weights is undoubtedly one of the best which has ever been made with reference to accuracy in the individual weighings and uniformity in the conditions and method of weighing. It is only to be regretted that the series is not more extensive. Regarding the racial homogeneity of the material Retzius says (*loc. cit.* p. 55): "ich überzeugte mich aber in den allermeisten Fällen davon, dass sie eine echt schwedische Herkunft anzeigten." The method of weighing was as follows (*loc. cit.* p. 55): "Die Gehirne wurden ohne Abnahme der weichen Hirnhäute, in der Regel kurz nach der Herausnahme, d. h. nur nach dem Verlust einer dabei stets ausfliessenden geringen Menge Blut und Cerebrospinalflüssigkeit, direct auf die Waageschale gelegt." The series as published by Retzius gives the weights of 450 male brains, and 250 female. In addition to brain-weight, age, stature, and cause of death are recorded. After throwing out individuals incompletely recorded, and those falling outside the age limits 20—80, there was left available for this study 416 male records and 233 female.

Matiegka† has furnished some very valuable data for the student of brain-weight. His material came from the autopsies at two institutions in Prague, the Institut für gerichtliche Medizin, and the Pathologisch-Anatomische Institut. The series from the former source is the larger and more complete, and is the only one which is used in the present discussion. This includes the brain-weights of 372 males and 197 females, together with records of age, stature, skull-length and skull-breadth. The individuals were all adults between the ages of 20 and 80. The great majority of them were Czechs. The method of weighing the brain

* Retzius, A.: "Ueber das Hirngewicht der Schweden," *Biol. Untersuchungen*, N. F. Bd. ix., Cap. iv. pp. 51—68, 1900.

† Matiegka, H.: "Über das Hirngewicht, die Schädelkapazität und die Kopfform, sowie deren Beziehungen zur psychischen Thätigkeit des Menschen," *Sitzber. des kön. böhmischen Gesellsch. d. Wissensch. Mathem.-Naturwiss. Classe*, Jahrg. 1902, No. xx. pp. 1—75.

was that usually followed: the pia and arachnoid were not removed before weighing. The special value of this material of Matiegka's lies in the fact that it is the most extensive series of brain-weights in which skull characters are so recorded as to make it possible to determine their correlation with the weight of the brain. In addition, data are given for the determination of the correlation between brain-weight and stature, and brain-weight and age. Unfortunately Matiegka's material is open to criticism in certain important respects. In the first place detailed tables showing the exact records for each individual are not given, but instead the material is thrown into the form of correlation tables. In making up these tables the units of grouping were not altogether wisely chosen. This results in introducing a certain error into the absolute values of the constants deduced from these tables. The exact cause, nature and amount of this error will be pointed out later in the paper. Again, the skull-length and skull-breadth were measured in a very unreliable manner. Regarding the method of making these measurements Matiegka says (*loc. cit.* p. 46): "Bei dem von mir verarbeiteten Materiale und zwar in beiden Instituten wurde gewöhnlich auch die *Länge* und *Breite* des *Schädeldaches* d. i. an dem behufs der Hirnentnahme vorgenommenen *Horizontalschnitte* gemessen. Das so erlangte Längenmass ist daher bedeutend *kürzer* als die *grösste Schädellänge*, die Breite wohl häufig etwas *kleiner* als die *grösste Schädelbreite**." The effect of this procedure on the biometric constants is discussed later in this paper. My chief reason for including this somewhat questionable material was for the sake of comparison, and because reasonably long series of brain weighings are not so plentiful as to allow one who would study the subject a great range of choice in material.

The data on the brain-weight of the English were very kindly placed at my disposal by Prof. H. H. Donaldson. He was able to obtain, some years ago, a copy of the original detailed manuscript tables which the English anatomist Marshall had compiled from Boyd's original data collected at the St Marylebone Infirmary and the Somerset County Lunatic Asylum. These detailed tables were never published, though it was on them that Marshall's well-known paper, "On the Relations between the Weight of the Brain and its Parts and Stature and Mass of the Body in Man †," was based. For the privilege of examining and using this unique and valuable material I am very grateful to Prof. Donaldson.

From the biometrical standpoint the raw material available for a statistical study of the weight of the brain is peculiarly complex. The great bulk of the statistics consists of material gathered at the autopsies performed in large general hospitals or other public institutions of similar character. The result of this is that the only large collections of brain-weight data available are not representative "random" samples of the general population. Instead they represent a group of the population which has been subjected to a rather stringent selective process of a peculiar kind. It would be very difficult, if not impossible, to formulate all

* Italics Matiegka's.

† *Jour. Anat. and Physiol.* Vol. xxvi. pp. 445—500, 1892.

the factors which contribute to the differentiation of the "general hospital population" from the "general population" of the same locality. Of some of them, however, we may be fairly certain. In the first place, there are many classes (social) of the general population which will never be represented in any significant proportion in the general hospital population. Furthermore, the nature of the injury or disease from which an individual is suffering in many cases determines whether the individual shall be in a hospital. On this point, Greenwood*, in an able discussion of the matter, says: "Evidently the population of a general hospital will chiefly consist of: (i) persons acutely ill, (ii) those suffering from surgical injuries or diseases, (iii) sufferers from medical affections requiring special treatment. Chronic maladies of old age, such as bronchitis, indeed, any highly chronic disease, will be under-represented in comparison with the general death-rate. Similarly, the number of cases of valvular heart disease and rarer disorders, such as *Diabetes Mellitus* or *Insular Sclerosis* and other nervous lesions, will be above the general average."

In addition to the selection which occurs in the formation of the general hospital population there is a still farther weeding out when we come to deal with autopsy records, for the reason that not every individual dying in a hospital is subjected to a post-mortem examination. Whether there shall be an autopsy or not in a given case depends on several factors, one of which is the cause of death. The individuals whose last illnesses have given doubtful or rare clinical features are more likely to be subjected to a post-mortem examination, other things being equal, than the individuals in whose case the fatal illness has run a perfectly typical clearly cut course of some common disease. Consequently there is a tendency for the statistics to be unduly weighted with deaths from some of the rarer maladies. There can be no doubt that the statistical constants relating to any character of the body which is in any way affected by the disease causing death will be different, in material coming from hospital and pathological laboratory autopsy returns, from those which would be obtained could we get a perfectly random sample of the general population dying outside a hospital, and subjected to post-mortem examination regardless of the cause of death.

These peculiarities attendant upon hospital autopsy records are of particular importance when the character studied is the weight of the brain, for the reason that this character is definitely affected both by the age of the individual, and, in certain cases, by the nature of the disease causing death. It is evident that there will be a more or less definite relation between the nature of the cause which brings an individual into a general hospital and the age of the individual. This combined relation of age and disease is a factor of importance in analysing brain-weight data. In what manner will be apparent from a moment's consideration. Suppose we take the first of Greenwood's classes of the general

* Greenwood, M.: "A First Study of the Weight, Variability and Correlation of the Human Viscera, with special reference to the Healthy and Diseased Heart." *Biometrika*, III. pp. 63-83, 1904, p. 65.

hospital population mentioned above, namely, "persons acutely ill." It is at once clear that this will include two sub-groups. First in number and importance will be the group of individuals suffering from diseases medically classified as "acute" in the strict sense of the term, for example, typhoid fever. Second will be the group of individuals acutely ill at the termination of a long-standing chronic disease. These individuals in most instances have been cared for at home as long as the disease remained in the chronic or sub-acute form, and only go into the hospital when it becomes acute. A good example of such cases is afforded by Bright's disease. There can be little doubt on *a priori* grounds that the mean age of the individuals will be lower in the first as compared with the second of these groups. This is shown to be the case by the actual statistics in the brain-weight series where "cause of death" is tabulated. In the lower age groups the causes of death returned are preponderantly "acute" in the strict sense. In the higher age groups we get a preponderance of the chronic affections. Now it is altogether likely that the acute illness which leads to death in a comparatively short time has much less effect on the weight of the brain than the chronic "wasting" sickness. So, then, the general result is that in the higher age classes where the brain-weight has decreased as the natural result of senescence there is a further artificial lowering on account of the preponderance of individuals who have been afflicted with "wasting" diseases. On the other hand the returns during early adult life give mean values for the brain-weight which are probably nearer the true normal value for the general population.

In the present paper it was desired to consider only adult brain-weights and consequently only material which fell in age between 20 and 80 years was usually used. It is the general opinion of anatomists (cf. for example, Ziehen, *loc. cit.* p. 359, and Marchand, *loc. cit.* p. 404), that after the age period 15—20 there is very little increase of weight in the brain with advancing age. In other words the brain is considered to attain practically its complete growth in about the first 20 years of life. According to Marchand (*loc. cit.* p. 402 *et seq.*) the maximum brain-weight remains practically constant till the individual is about 50 years old. After that age he believes that senile degeneration begins. Accordingly, in the discussion of the Marchand data, I have considered the period from 15—80 years to constitute the "adult period," so far as brain-weight is concerned. As a matter of fact, the result would have been but little different had the period 20—80 years been used in this case (as it was with all the other data), because there are only 36 males and 17 females falling in the age class 15—19, and these individuals are fairly evenly distributed among the brain-weight classes as will be seen by consulting Tables 17 and 18 of the Appendix. When the work was begun I had, of course, no means of knowing how it would turn out, so it was necessary to decide how to treat the material on the basis simply of a careful general inspection of the statistics and of the opinion of other workers on the subject. As one point which I wished especially to investigate was the change of brain-weight with age, it became a nice problem as to how to handle the

material so as to best get at this. I finally decided after a good deal of consideration to adopt provisionally Marchand's view stated above, viz., that the weight of the brain reaches a maximum between the ages 15 and 20, remains constant till about age 50, then declines through the old age period. Acting on this plan I separated the material in each case into what I have called a "young" and the "total" group. The "young" series included the individuals falling between the ages 20 to 50 (in the Hessian material, 15—50, and in the Bohemian 20—59 were the limits, in the former case from choice, in the latter from necessity). The "total" series included all the individuals between ages 20 and 80 (in the Hessian series 15 was the lower limit). The results show that on the whole this method of handling the material was adequate, considering the ends to be gained and the amount of material available.

3. *Fundamental Constants.*

As a preliminary to the discussion of the correlation of brain-weight with other characters it is necessary to exhibit and discuss the constants, measuring type and variability of the characters considered. Certain problems which are of considerable interest on their own account present themselves here. Of first importance perhaps is the question as to the amount of differentiation in respect of brain-weight which exists between different sub-races of men, both in type and variability. Further, the rather extensive material worked over makes it possible to settle the problem of the relative variability of the sexes with respect to the weight of the brain. On this point Pearson (*loc. cit.*) has made a brief communication based on an analysis of four short series of English data, Bischoff's Bavarian series, and a French series. His general conclusion is that in respect of brain-weight the sexes are sensibly equally variable. Another interesting problem which merits discussion here is as to how the relative variability in brain-weight compares with the variability of other organs and characters of the body.

In Table I are exhibited the values of the Means, Standard Deviations and Coefficients of Variation together with their probable errors for each of the characters studied in this work. While, of course, the primary object of study is the weight of the brain, yet it is necessary for the correlation determinations that we have the fundamental constants for the other characters, age, stature, etc. To effect economy of space the constants for these other characters have been included in this first table. The frequency distributions from which the constants have been deduced will be found in the fundamental tables, numbered in Arabic numerals from 1 to 44, collected at the end of this paper. Regarding the calculation of the constants the following explanations should be made. In preparing the correlation tables from the raw statistical material the following values for the units of grouping were chosen, and used uniformly throughout the work, except in certain cases where it was impossible to keep to them.

Character	Standard Unit of Grouping
Brain-weight ...	50 grams
Age ...	5 years
Stature ...	3 centimetres
Skull length ...	5 millimetres
Skull breadth ...	5 millimetres
Body-weight ...	5 kilograms

These standard units were chosen after considerable study and experimenting and are believed to be the best values for the data discussed. However, it has been shown recently by other workers* that "the system of grouping adopted is within wide limits immaterial." An examination of those cases recorded in the present paper where it was necessary to use different units of grouping—notably in the Matiegka data where the brain-weights were grouped into 100 gram classes and the ages into 10 year classes—leads to the same conclusion.

The standard deviation was evaluated according to the equation $\sigma = \sqrt{\mu_2}$. In obtaining μ_2 Sheppard's correction was used throughout for the characters brain-weight, stature, skull length, skull breadth and body-weight. The uncorrected "rough" moment was used in getting the standard deviation in age, as in this case there is no approach to high contact at either end of the range.

The decimals have been retained to three places in the tabulated values in order that the significant value of the first place may be seen. It will be understood, of course, that in the computations the decimals were retained to a larger number of places for arithmetical reasons.

4. *Brain-weight Types.*

In brain-weight work hitherto it has not been possible to make accurate comparisons of the mean weight of the brain in different races. There were two reasons for this: one that the probable errors of the means were not determined, and the other that no method was available by which allowance could be made for the differences in the mean stature and age of the samples of material to be compared. Obviously if brain-weight is correlated with stature and age, we should expect to get a considerable difference between the mean brain-weight of two groups which differed widely with respect to these other characters. Inasmuch as a knowledge of the degree of correlation between these characters affords a method whereby the material can be reduced to a "standard stature-age base," it will be worth while to examine the actual differences in brain-weight types in the four racial groups here discussed.

* "Assortative Mating in Man." A Cooperative Study. *Biometrika*, Vol. II. pp. 481—498, 1903.

TABLE I. *Fundamental Constants.*

Race	Character	Mean						Standard Deviation		Coefficient of Variation	
		No.	♂	Table	No.	♀	Table	♂	♀	♂	♀
Swedes ...	Brain-weight (Total) ...	416	1400·481 ± 3·516	1	233	1252·682 ± 4·452	2	106·329 ± 2·486	100·757 ± 3·148	7·592 ± ·179	8·043 ± ·253
"	" (Young) ...	262	1415·267 ± 4·550	3	127	1269·488 ± 6·317	4	109·180 ± 3·217	105·543 ± 4·467	7·714 ± ·229	8·314 ± ·354
Hessians	" (Total) ...	475	1391·737 ± 3·487	13	281	1259·875 ± 4·119	14	112·675 ± 2·466	102·368 ± 2·642	8·096 ± ·178	8·125 ± ·233
"	" (Young) ...	291	1405·756 ± 4·402	15	173	1280·202 ± 5·223	16	111·328 ± 3·113	101·841 ± 3·693	7·919 ± ·223	7·955 ± ·290
Bohemians	" (Total) ...	372	1454·839 ± 3·973	27	197	1310·914 ± 4·650	28	113·608 ± 2·813	96·772 ± 3·288	7·809 ± ·197	7·382 ± ·252
"	" (Young) ...	266	1460·150 ± 4·731	25	133	1313·910 ± 5·453	26	114·395 ± 3·345	93·227 ± 3·855	7·835 ± ·231	7·095 ± ·295
"	" (Skull) ...	299	1463·712 ± 4·503	29	159	1321·698 ± 5·073	30	115·440 ± 3·159	94·840 ± 3·587	7·887 ± ·219	7·176 ± ·273
Bavarians	" (Total, Long*) ...	529	1363·185 ± 3·245	37	323	1220·356 ± 3·820	38	110·644 ± 2·295	101·776 ± 2·701	8·118 ± ·122	8·340 ± ·223
"	" (Young, Long*) ...	365	1369·110 ± 3·841	39	238	1235·504 ± 3·997	40	108·776 ± 2·716	91·421 ± 2·826	7·945 ± ·200	7·399 ± ·230
"	" (Total, Short*) ...	365	1357·466 ± 3·888	35	241	1218·776 ± 4·616	36	120·128 ± 2·749	106·246 ± 3·264	8·849 ± ·223	8·717 ± ·270
Swedes ...	Stature (Total) ...	416	169·789 ± ·225	1	233	158·710 ± ·297	2	6·807 ± ·159	6·719 ± ·210	4·009 ± ·094	4·233 ± ·133
"	" (Young) ...	262	170·176 ± ·280	3	127	159·673 ± ·418	4	6·728 ± ·198	6·987 ± ·296	3·954 ± ·117	4·375 ± ·186
Hessians	" (Total) ...	475	167·359 ± ·223	13	281	156·178 ± ·277	14	7·189 ± ·157	6·895 ± ·196	4·296 ± ·094	4·400 ± ·125
"	" (Young) ...	291	167·294 ± ·282	15	173	156·980 ± ·384	16	7·118 ± ·199	7·490 ± ·272	4·255 ± ·119	4·771 ± ·173
Bohemians	" (Young) ...	266	169·417 ± ·303	25	133	157·650 ± ·418	26	7·324 ± ·214	7·152 ± ·296	4·323 ± ·127	4·537 ± ·188
Bavarians	" (Total, Short*) ...	365	166·549 ± ·226	35	241	154·712 ± ·270	36	6·393 ± ·160	6·213 ± ·191	3·838 ± ·096	4·016 ± ·124
Swedes ...	Age (Total) ...	416	45·024 ± ·452	5	233	47·629 ± ·671	6	13·671 ± ·320	15·195 ± ·475		
"	" (Young) ...	262	36·317 ± ·327	7	127	35·689 ± ·480	8	7·847 ± ·231	8·027 ± ·340		
Hessians	" (Total) ...	475	42·889 ± ·521	17	281	44·795 ± ·656	18	16·843 ± ·369	16·304 ± ·464		
"	" (Young) ...	291	31·572 ± ·390	19	173	34·061 ± ·497	20	9·861 ± ·276	9·685 ± ·351		
Bohemians	" (Total) ...	372	45·699 ± ·523	27	197	41·447 ± ·792	28	14·957 ± ·370	16·482 ± ·560		
Bavarians	" (Total, Long*) ...	529	43·171 ± ·396	37	323	40·333 ± ·561	38	13·495 ± ·280	14·954 ± ·397		
"	" (Young, Long*) ...	365	35·582 ± ·255	39	238	32·731 ± ·340	40	7·216 ± ·180	7·768 ± ·240		
Bohemians	Skull length (Young) ...	299	176·547 ± ·287	29	159	170·142 ± ·294	30	7·368 ± ·203	5·500 ± ·208	4·173 ± ·115	3·233 ± ·122
"	" breadth (Young) ...	299	149·841 ± ·260	31	159	144·953 ± ·296	32	6·654 ± ·184	5·530 ± ·209	4·441 ± ·123	3·815 ± ·145
Bavarians	Body-weight (Total, Short*) ...	365	49·925 ± ·376	41	241	42·894 ± ·461	42	10·646 ± ·266	10·601 ± ·326	21·324 ± ·608	24·715 ± ·804

* Cf. p. 17.

Taking the gross values given in Table I the following Table II has been prepared to facilitate comparison.

TABLE II.
Brain-weight Types.

	Hessians	Bavarians	Swedes	Bohemians
<i>Total Males</i>				
Mean brain-weight	1391.737	1363.185	1400.481	1454.839
Mean age ...	42.889	43.171	45.024	45.699
Mean stature ...	167.359	166.549	169.789	—
<i>Young Males</i>				
Mean brain-weight	1405.756	1369.110	1415.267	1460.150
Mean age ...	31.572	35.582	36.317	40.545*
Mean stature ...	167.294	—	170.176	169.417
<i>Total Females</i>				
Mean brain-weight	1259.875	1220.356	1252.682	1310.914
Mean age ...	44.795	40.333	47.639	41.447
Mean stature ...	156.688	154.712	158.710	—
<i>Young Females</i>				
Mean brain-weight	1280.202	1235.504	1269.488	1313.910
Mean age ...	34.061	32.731	35.689	35.613†
Mean stature ...	156.980	—	159.673	157.650

It is apparent at once that, considering the magnitude of the probable errors, there are significant differences between the Bavarians, Swedes, and Bohemians, with respect to brain-weight, in both sexes and age classes. Between the Swedish and Hessian means the differences are smaller, and as the following table shows, are not significant when their probable errors are taken into account:

Total Males: Swedish mean—Hessian mean = 8.744 ± 4.952 .

Total Females: Hessian mean—Swedish mean = 7.193 ± 6.065 .

Young Males: Swedish mean—Hessian mean = 9.511 ± 6.331 .

Young Females: Hessian mean—Swedish mean = 10.714 ± 8.197 .

In no case is the difference as great as even twice its probable error, hence we must conclude that the differences exhibited might, so far as the extent of material allows us to judge, be due to random sampling.

* This value was calculated by taking the first four age classes of the "total" series. It includes more individuals than the "young" series for the other characters. This was the only way in which the mean age of the "young" series in this case could be even approximated to, as the raw material given by Matiegka is incomplete in this respect. The age as given is probably a little too high, but the error cannot be great.

Is this agreement between the Hessian and Swedish peoples in the matter of brain-weight real, or only apparent and the result of compensating differences in the other correlated characters? An answer to this question can be reached in two ways; either by reducing one set to the same "stature-age base" as the other and then comparing results, or by analyzing the effects on the brain-weight of the observed stature and age differences in the two sets of material. Both of these methods depend on the use of characteristic equations, the derivation of which will be described further on in the paper. For the present I shall make practical use of such equations without further discussion of their derivation or validity. Table II shows that in the samples with which we are dealing the Hessians, both male and female, average *younger* and *shorter* than the Swedes. Reducing the Hessians to the same "stature-age base" as the Swedes, by means of the appropriate equations given on p. 63 *infra*, the following results are obtained:

TABLE III.

The probable brain-weight of a group of Hessian ♂♂ having the same age and stature as the Swedish ♂♂ (Total)						Equation
						=1396.480 (23)
Swedish brain-weight observed						=1400.481
Swedish <i>heavier</i> . Difference						= 4.001
The probable brain-weight of a group of Hessian ♀♀ having the same age and stature as the Swedish ♀♀ (Total)						=1258.232 (25)
Swedish brain-weight observed						=1252.682
Hessian <i>heavier</i> . Difference						= 5.550
The probable brain-weight of a group of Hessian ♂♂ having the same age and stature as the Young Swedish ♂♂						=1407.457 (24)
Swedish brain-weight observed						=1415.267
Swedish <i>heavier</i> . Difference						= 7.810
The probable brain-weight of a group of Hessian ♀♀ having the same age and stature as the Young Swedish ♀♀						=1283.540 (26)
Swedish brain-weight observed						=1269.488
Hessian <i>heavier</i> . Difference						= 14.052

These differences after the stature-age corrections are made are extremely small. This is particularly well shown if they are reduced to a relative basis, by expressing the differences as percentages of the observed Swedish brain-weight:

The difference between Total Swedish ♂♂ and Hessians (calculated) = 0.29% of the observed Swedish brain-weight.

The difference between Total Swedish ♀♀ and Hessians (calculated) = 0.44% of the observed Swedish brain-weight.

The difference between Young Swedish ♂♂ and Hessians (calculated) = 0.55% of the observed Swedish brain-weight.

The difference between Young Swedish ♀♀ and Hessians (calculated) = 1.11% of the observed Swedish brain-weight.

It appears then that, so far as the available material may be considered valid as representing the whole population, the conclusion is justified that the Hessian and Swedish peoples are sensibly alike in respect to their brain-weight. The agreement would be closer than that actually observed if the assumption made in the course of reasoning here followed, that the regression of brain-weight on age and stature is strictly linear, were exactly true. As will be shown later these regressions are not strictly linear but they approach linearity with sufficient closeness to serve for all practical purposes. This, together with the difference in age distribution of the "total" and "young" series, also accounts for the fact that while in the "total" series and male "young" series the gross differences between Swedes and Hessians are lowered when we reduce to a common "stature-age base," these differences are slightly increased, on the other hand, when we deal in the same way with the shorter female "young" series.

This is in agreement with the general fact that these peoples are probably the most closely related ethnically of any with which we are dealing in the present paper. The Swedes may be considered to be among the purest representatives of the original blonde, dolichocephalic Teutonic race (Ripley* and Deniker†). In the case of the Hessians some intermixture of this Teutonic with the brachycephalic, characteristically brunette Alpine type has occurred. The differentiation from the Swedes in such important characters as skull form and stature is not great however‡.

Turning now to the other racial groups discussed, viz., the Bavarians and Bohemians (Czechs), we find as would be expected, that the differences in brain-weight are greater. Using the Hessian data as a basis for comparison, the gross differences with their probable errors are exhibited in the following table:

Total Males :	Hessian mean—Bavarian mean = 28.552 ± 4.763 .
Total Females :	Hessian mean—Bavarian mean = 39.519 ± 5.618 .
Young Males :	Hessian mean—Bavarian mean = 36.646 ± 5.842 .
Young Females :	Hessian mean—Bavarian mean = 44.698 ± 6.577 .
Total Males :	Bohemian mean—Hessian mean = 53.102 ± 5.286 .
Total Females :	Bohemian mean—Hessian mean = 51.039 ± 6.212 .
Young Males :	Bohemian mean—Hessian mean = 54.394 ± 6.462 .
Young Females :	Bohemian mean—Hessian mean = 33.708 ± 7.551 .

In all cases the differences are seen to be well above what might arise from errors in statistical sampling. Reducing to a common "stature-age base" by the method followed above the following results are obtained:

* Ripley, W. Z.: *The Races of Europe*, New York, 1899, pp. xxxii, 624.

† Deniker: *The Races of Man*, London and New York, 1900, pp. xxiii, 328 and 611.

‡ This is well shown graphically in the maps indicating the distribution of stature and cephalic index in Europe, given by Ripley (*loc. cit.* pp. 96 and 53). Cf. also Deniker, *loc. cit.* pp. 328 and 329.

TABLE IV.

	Probable Brain-weight of a group of Hessians of the same <i>sex</i> , <i>age</i> and <i>stature</i> as the	Mean Brain-weight <i>observed</i> (Bavarian or Bohemian)	Difference expressed as in excess or defect of Hessian values	Difference as per cent. of observed mean (Bavarian or Bohemian)	Equation on which Hessian estimate is based
Bavarian ♂♂, Total	1388.984	1363.185	-25.799	-1.9%	No. 23, p. 63
" ♀♀, Total	1265.137	1220.356	-44.781	-3.7%	" 25, "
" ♂♂, Young	1397.157*	1369.110	-28.047	-2.0%	" 24, "
" ♀♀, Young	1277.317*	1235.504	-41.813	-3.4%	" 26, "
Bohemian ♂♂, Total	1394.570†	1454.839	+60.269	+4.1%	" 23, "
" ♀♀, Total	1259.310†	1310.914	+51.604	+3.9%	" 25, "
" ♂♂, Young	1399.527‡	1460.150	+60.623	+4.2%	" 24, "
" ♀♀, Young	1278.935‡	1313.910	+34.975	+2.7%	" 26, "

This table brings out several points of considerable interest. In the first instance is to be noted the general effect of reducing the Hessians to the same "stature-age base" as the other races, upon the interracial differences in mean brain-weight. In the case of the Bavarians the deviations from the Hessian means are reduced slightly in both male series, and the "young" female series, when stature and age differences are eliminated. In the "total" female series the difference is increased over the original gross difference. The explanation for this discrepancy in the female "total" series is to be found in a peculiar abnormality which this series shows in its elemental frequency distribution, and which will be discussed later (p. 40). In the case of the Bohemians we get the somewhat remarkable result that a reduction to a common "stature-age base" actually increases the differences of this racial group in brain-weight as compared with the Hessians. Or in other words, in the samples with which we are dealing the stature and age differences act in a compensatory way and bring the mean brain-weights closer together than they would be if we dealt with selected samples of the populations, each sample having the same mean age and stature. The fact already noted (p. 18) that the mean brain-weights deduced from Matiegka's tables for the Bohemians are somewhat too large, may now be examined in detail. This Bohemian material was published by Matiegka in the form of correlation tables with unduly large units of grouping (cf. Tables 25 to 28, Appendix). The base unit for brain-weight was 100 gr. Now in calculating the general population mean from these tables one assumes that the individuals in each elemental frequency group centre in brain-weight at the mid-point of that group. Thus, the individuals recorded as having a brain-weight of between 1300 and 1400 grams are assumed to centre at 1350 gr. But evidently this assumption will not be true except at the middle of the whole range. For example, the brain-weights recorded

* This assumes that the mean stature of the Bavarians would be the same in the "young" group as it is in the "total" group. The error introduced by this procedure is practically negligible.

† Here again, on account of lack of data, the mean stature is assumed to be the same in "total" and "young" groups.

‡ See footnote on p. 24.

as between 1500 and 1600 will centre somewhat below 1550. Now, of course, if the distribution is exactly or approximately normal and the number of individuals is sufficiently large, the errors from this cause on one side of the general population mean will balance those on the other, and we shall still be able to get a very close value for this mean from the frequency distribution. Unfortunately, in Matiegka's series, however, the total numbers are not sufficiently large to overcome entirely this error. So we have the following differences: by direct calculation from the individual observations Matiegka finds for the mean brain-weight of the "young" (20—59) series in the male 1450·4 gr., in the female 1305·5 gr. Our corresponding values are 1460·150 gr. and 1313·910 gr. or there is an excess of 9·7 gr. and 8·4 gr. respectively. For the "total" series (20—80) I have calculated from regression values which Matiegka gives (p. 7), based on the individual observations, general population means which gives values as follows: males 1441·4 gr., females 1294·8 gr. The corresponding values from the tables are: males 1454·8 gr., females 1310·9 gr., or the excess of the table means is 13·4 gr. for the males and 16·1 for the females. These differences are small and for practical purposes negligible.

The general conclusion may be drawn that, *apart from all differences in stature, and in the mean age of the samples studied*, the Bavarian mean brain-weight is lower than the Hessian (roughly about 2%), and the Bohemian mean brain-weight is higher than the Hessian (roughly about 3·5%).

These results seem to be of some importance as indicating a method whereby brain-weight may have some scientific validity as an anthropological character. This can hardly be said to be the case when nothing more is done than to tabulate means without probable errors, and no attempt is made to get rid of disturbing stature and age effects. Interracial differences in brain-weight may mean something or nothing. With modern biometrical methods it is possible to measure exactly these differences, and when such methods are used it is the belief of the writer that brain-weight can become a really significant anthropological character. In the cases discussed here we see ethnic affinities and differences clearly reflected in the brain-weight. Of the four racial groups studied the two most closely related in origin and general anthropological characters, the Swedes and the Hessians, have mean brain-weights sensibly identical. The Bavarians and Bohemians, though close neighbours geographically, arise from totally distinct ethnic stocks ("Alpine" and Slav respectively) and associated with this we find a wide difference in the weight of the brain.

On the question of the homogeneity of brain-weight statistics, some evidence is furnished in the third and fourth columns of Table IV. If the inclusion of aged persons (50 years and over) introduced any considerable element of heterogeneity so far as brain-weight constants are concerned it would be expected that the interracial differences in the means would not be equal in the "total" and in the "young" series. As a matter of fact in the material here discussed they are sensibly equal, or perhaps better, they are not significantly different. The whole

question of the homogeneity of this material will be treated fully in connection with the discussion of the variability in brain-weight.

The interesting questions brought up by this table of means, regarding sexual differences, association of brain-weight with other characters, etc., will be discussed in later sections of the paper.

5. *Variation in Brain-weight. Homogeneity of Material.*

Variability in the weight of the brain has been subjected to exact investigation by only one worker, Pearson (*loc. cit.*), so far as is known to the writer. He deduced from his material (cf. p. 15 *supra*) coefficients of variation ranging in value from 7.93% to 10.64%, the higher values being from admittedly heterogeneous series.

The numerical values for the variation constants and their probable errors found in the present work are given in Table I.

The question of homogeneity of material should be first discussed. For reasons which have been set forth above it would be hopeless to look for any high degree of homogeneity in any collection of human brain-weighings at present available. The best we can hope for is a fair degree of homogeneity, and reasonably the same degree in different series which are to be compared. Unfortunately there is not available here, as in the case of craniometrical investigations, series in which fair homogeneity can be inferred with high probability, so that it is not possible to make a direct estimate by comparing variabilities with such a "known base." Instead resort must be had to indirect methods. The best of such indirect methods is based on the fact that if a random sample be taken from a *homogeneous* collection of material the variation constants for the sample and the whole collection will not significantly differ. On the contrary if the material is non-homogeneous such a sampling will give different values for the constants. If the sample be *selected*, i.e. not random, the variation constants for the character selected will of course be lowered. Now in the material as treated here we have in the "young" series for each racial group a *selection* from the "total" series, but a selection based on age, not on brain-weight directly. If there were no correlation between brain-weight and age such a selection on an age basis would be, of course, a random sample so far as brain-weight is concerned. Unfortunately for the argument, there is, as will be shown later, a sensible though in general low correlation between age and brain-weight. This being the case it would be expected that such a selection as has been made in separating out the "young" from the "total" series would result in a lowering of the standard deviation and coefficient of variation in brain-weight. Now, as a matter of fact, as the following table shows, the correlation between brain-weight and age is so low that in the relatively small series under discussion, the "young" series forms practically a random sample of the "total" series, within the limits of error, with respect to brain-weight.

TABLE V.

Difference in Variation Constants between "Young" and "Total" Series.

	♂		♀	
	S. D.	C. of V.	S. D.	C. of V.
Swedes	+2·851 ± 4·066	+·122 ± ·291	+ 4·786 ± 5·465	+·271 ± ·435
Hessians	-1·347 ± 3·971	-·177 ± ·285	- 527 ± 4·541	-·170 ± ·372
Bavarians	-1·888 ± 3·556	-·173 ± ·234	-10·357 ± 3·909	-·941 ± ·320
Bohemians	+ 787 ± 4·371	+·026 ± ·304	- 3·545 ± 5·067	-·287 ± ·388
" (Skull)*	+1·832 ± 4·230	+·078 ± ·295	- 1·932 ± 4·866	-·206 ± ·372

Difference + when "Young" is greater.

" - " " less.

In only one case—the Bavarian females—is the difference as large as its probable error, and in this case the difference is not three times the probable error. The conclusion seems justified that the series are reasonably homogeneous in other respects than age. The age distribution is such as to exclude growth effects, and, as the differences indicate, the effects of senescence on brain-weight are so insignificant that for practical purposes the material may be considered sufficiently homogeneous to warrant further biometrical study. From the character of the differences it would appear that the most homogeneous series are, on the whole, the Swedish and the Bohemian.

A direct examination of the standard deviations and coefficients of variation confirms the conclusion. In the following table I have arranged in order according to ascending value, the variation constants for the "total" series, using as the basis for the grouping the coefficient of variation:

TABLE VI.

Comparison of Different Races in Respect to Variation in Brain-weight and Skull Capacity.

	Males			Females	
	S. D.	C. of V.		S. D.	C. of V.
Swedes	106·329	7·592	Bohemians	96·772	7·382
Bohemians	113·608	7·809	Swedes	100·757	8·043
Hessians	112·675	8·096	Hessians	102·368	8·125
Bavarians	110·664	8·118	Bavarians	101·776	8·340
English†... ..	124·48	9·20	English†	118·7	9·72
Skull Capacity, English‡	—	8·28	Skull Capacity, English‡	—	8·68
" " Germans§	—	7·74	" " Germans§	—	8·19

* See p. 17 and Table I. for the series here referred to.

† Pearson: *The Chances of Death*, Vol. I. p. 321.‡ W. R. Macdonell: *Biometrika*, Vol. III. p. 221.§ Pearson: *The Chances of Death*, Vol. I. p. 333.

All of the four series used in this paper are in good agreement, both among themselves and with the skull capacity values. They are distinctly lower than the figures from the admittedly heterogeneous, Reid, Peacock, Sims and Clendinning English series, worked over by Pearson. Taking all the evidence together we are driven to the conclusion that the series are fairly homogeneous. If any one of our series is markedly heterogeneous all the others must be equally so, which would be a very improbable result. That the series cannot be very heterogeneous in their make-up is also shown by the values of the coefficients of variation for skull capacity from two admittedly homogeneous series, the Whitechapel skulls studied by Macdonell, and Ranke's Bavarian series.

A comparison of the variability in brain-weight with that shown by other organs and characters of the human body may next be undertaken. I have arranged in the following table (VII) the coefficients of variation for a variety of characters which have been studied by biometrical workers. The arrangement is in general that of descending order of values in the male series. The attempt has been made in the table to include representatives of all the different classes of organs and characters for which we have biometric data available.

The most noticeable and remarkable fact brought out by the foregoing table is that with the exception of capacity, all skull characters are roughly only about half as variable as brain-weight. Some such a relation as this might have been predicted, on the general ground that brain-weight measurements and statistics are on many accounts rather "loose," and would *indicate* a higher variability than would exact measurements on skulls, even though it had no real existence. Such reasoning, however, takes no account of the agreement, which is really remarkably close when we recall the numerous sources of error in brain-weight returns, between skull capacity and brain-weight in their variability. All will admit that capacity is the most difficult skull character to measure accurately, yet no one would maintain that the difference in variability between cephalic index, for example, and skull capacity was entirely, or even in any considerable part, due to the element of error in the measurement of the latter. The agreement in variability between skull capacity and brain-weight is, of course, to be expected on theoretical grounds. That it should turn out in practice to be so close is a first-rate guarantee of the general trustworthiness of brain-weight statistics.

As to the explanation of the great variability in brain-weight and skull capacity as compared with the other skull characters we may tentatively reason about the matter in the following way. If the list of organs and characters given in the foregoing table be examined a natural division into three groups almost immediately suggests itself. First, we have at the bottom of the list the "bone" measurements, in general including all those characters which depend primarily for their values on the dimensions of various parts of the skeleton. These characters give values for the coefficient of variation up to from 5 to 7, certain of the mandibular variabilities exceeding this limit. Next comes the group giving values for the coefficients of from 7 to 10, with the limits fairly sharply marked off.

TABLE VII. *Coefficients of Variation for Man.*

	♂	♀
Weight of Spleen (General Hospital Population)*	50.58	—
" " (Healthy)†	38.21	—
Dermal Sensitivity‡	35.70	45.70
Weight of Heart (General Hospital Population)*	32.39	—
Keeness of Sight‡	28.68	32.21
Weight of Kidneys (General Hospital Population)*	24.63	—
Weight of Body (Bavarians)... ..	21.32	24.715
Weight of Liver (General Hospital Population)*... ..	21.12	—
Swiftness of Blow‡	19.4	17.1
Weight of Heart (Healthy)†	17.71	—
" " Kidneys (Healthy)†	16.80	—
Breathing Capacity‡	16.6	20.4
Strength of Pull ‡	15.0	19.3
Weight of Liver (Healthy)†... ..	14.80	—
Height of Mandible (English, both sexes)§	11.73	11.73
Weight of Body (English)‡	10.37	13.37
Skull Capacity (Etruscan) 	9.58	8.54
Brain-weight (French)‡	9.16	9.14
Skull Capacity (Modern Italian) 	8.34	8.99
" " (English)¶	8.28	8.68
" " (Egyptian Mummies) 	8.13	8.29
Brain-weight (Bavarian)	8.118	8.340
" " (Hessian)	8.096	8.125
" " (Bohemian)	7.809	7.382
Skull Capacity (Modern German) 	7.74	8.19
" " (Naqada) 	7.72	6.92
Brain-weight (Swedish)	7.592	8.043
Skull Capacity (Parisian French) 	7.36	7.10
" " (Aino) 	7.07	6.90
Mandible, Distance between Foramina mentalia (English, both sexes)§	6.23	6.23
Length of Forearm**	5.24	5.21
" " Femur (French)‡	5.05	5.04
" " Tibia	4.975	5.365
" " Humerus (French)‡	4.89	5.61
" " Radius	4.87	5.23
Skull, Height to Breadth Index (English)¶	4.86	4.16
" " Breadth to Height	4.83	4.17
Length of Finger (English Criminals)††	4.74	—
Skull, Ratio of Height to Horizontal Length (English)¶	4.61	4.10
Length of Foot (English)††	4.59	—
Skull, Cephalic Index for Horizontal Length (English)¶	4.38	3.99
Length of Cubit (English Criminals)††	4.36	—
Skull, Least Breadth of Forehead (English)¶	4.29	4.55
" " Height (English)¶	4.21	3.96
" " Length of Base (English)¶	4.07	4.11
" " Cephalic Index for Greatest Length (English)¶	3.95	4.03
Stature (English)**	3.99	3.83
Skull, Ratio of Height to Greatest Length (English)¶	3.80	4.21
" " Greatest Breadth (English)¶	3.75	3.54
" " Auricular Height (English)¶	3.73	4.12
" " Face Breadth (English Criminals)††	3.707	—
Skull, Cross Circumference (English)¶	3.70	3.97
" " Sagittal	3.63	3.90
Head Breadth (English Criminals)††	3.333	—
Skull, Length (English)¶	3.31	3.45
Head Length (English Criminals)††	3.154	—
Skull, Horizontal Circumference (English)¶	2.87	2.92

* Greenwood, M.: *Biometrika*, Vol. III. p. 66.† *Ibid.* p. 67.‡ Pearson, K.: *The Chances of Death*, Vol. I. pp. 293—377.§ Macdonell, W. R.: *Biometrika*, Vol. III. p. 225.|| *Ibid.* p. 221 (after Pearson).¶ *Ibid.* p. 222.** Pearson and Lee: *Biometrika*, Vol. II. p. 370.†† Macdonell, W. R.: *Biometrika*, Vol. I. p. 202.

Finally we have all the characters giving values above 10. Now as one passes from one end of the series to the other a definite biological relationship is plain. At the upper end of the series (coefficient of variation 10 and over) the organs and characters tabulated are such as depend in a very considerable degree for their values as determined by measurement, on the general *metabolic condition of the organism* as a whole at the time the measurements are made or immediately before. This will be freely admitted, I think, for such characters as "Dermal sensitivity," "Keeness of sight," "Weight of body," "Swiftness of blow," "Strength of pull," "Breathing capacity" and the like. The same thing, though less apparent perhaps, is, I believe, true when the characters are the weights of viscera. Indeed Greenwood's own results show this to be the case, when we get such different results for means, variabilities and correlation accordingly as we deal with the "general hospital population," "healthy" organs, or the same viscera in diseased conditions of different characters. Wynn* has only recently shown that in rabbits there is a considerable degree of probability that continued administration of digitalis will in a short time raise the mean weight of the heart appreciably, while at the same time the body weight is lowered. It is to be regretted that his series of experiments included so (statistically) few individuals.

Furthermore, it seems reasonable to assume that in this upper group the thing measured in the majority, if not in all cases, is not the thing natural selection has acted upon directly, allowing that it has acted at all. I think it may be fairly assumed that so far as natural selection has acted at all on these organs and characters, the selection has been in the direction of *ability to function properly* so as best to conserve the physiological economy of the organism as a whole, rather than in the direction of absolute size of organ or character. The physiologically balanced functioning with reference to the needs of the organism as a whole is the important thing in such organs as the spleen, pancreas, liver, etc. Absolute size of organ can hardly be a very close direct measure of ability to function well. So then, I am inclined to attribute the high variability observed in those organs and characters falling together in the uppermost part of the table to these two factors: (a) the value obtained by measurement depends to a considerable degree on the general metabolic condition of the individual at the time, and (b) the thing measured is not the thing with which natural selection, so far as it has acted at all, has had directly to do.

On the other hand, if we turn to the lowest group in the above table (coefficients of variation under 5—7 for the males) we find the two factors just mentioned almost exactly reversed. Here the characters are either of the skeleton directly, or in the case of the anthropometrical data are characters which closely depend for their measured values on the size of portions of the skeleton. Obviously the general metabolic condition of the organism has, within wide limits, little effect on the length of the femur or the skull, for example, and if there is an effect it manifests itself very slowly. Further it is to be presumed that the absolute

* *Journal of the American Medical Association*, Vol. XLIII. pp. 164, 165, 1904.

size is of greater direct selective value in the case of parts of the skeleton than in the case of organs like the liver, etc. In other words, size is much more directly related to proper functioning in the former than in the latter case. The skull may at first sight appear to form an exception here. It must be kept in mind, however, that the skull serves two very important—perhaps equally important—functions; viz., (1) the enclosing and protecting of the brain, and (2) the serving as a basis for the attachment of the complexes of muscles which actuate the masticatory apparatus and support and move the head. With reference to each of these factors natural selection may act on the skull. So far as the second factor at least is concerned, size of skull (in a broad sense) will be of selective value. So that here again, since size and function are interrelated, we should expect to find the results of selective action reflected in the size measurements of characters. In general, I think it can safely be maintained that the low variability shown in the group of characters under discussion is what might be expected to result from the operation of the factors just mentioned.

In the middle group (coefficients of variation ranging from 7 to 10 in the male) including brain-weight and skull capacity we seem to have also an intermediate condition, with respect to the two factors which have been mentioned as among the causes which contribute to the observed variability. In the first place, there can be no doubt in face of the evidence both from the biometrical and anatomical standpoints, that the cranial capacity is quite highly correlated with volume of the brain*. Admitting this, the discussion may be restricted to the brain. Now it has been known from the time of the earliest collection of brain-weight statistics that the weight of the brain is influenced to a certain extent by the general metabolic condition of the individual preceding death. I am inclined to think however that the extent of this influence has been over-estimated. My primary reason for this view comes from the analysis of the statistics themselves. If the metabolic condition of the individual preceding death influenced brain-weight to a marked degree, one would hardly expect to find the agreement shown in the constants of variation and correlation tabulated in this paper, when different groups of individuals with different distribution of ante-mortem affections were compared. We might expect by chance to get two groups in agreement, but on this supposition the odds would be great against getting four groups to agree so closely as they actually do. Furthermore, there is a certain amount of evidence from other sources indicating that the influence of ante-mortem general metabolic conditions on brain-weight, while always present as one factor, does not produce so marked an effect on the weight of the brain as on the size measurements of some of the organs in our most variable group. For example, Mühlmann† studied microscopically the brains of 24 individuals of different ages from birth to 90 years to determine the amount of pigment degeneration in the ganglion cells at the different ages. In the adults the causes of death included such divergent con-

* On the anatomical side, cf. Symington, *Nature*, Vol. 68, pp. 539—544.

† *Verhandl. d. deutsch. Pathol. Gesellsch.* Bd. III. pp. 148—157.

ditions as endocarditis, pneumonia cruposa, and nephritis chronica. Yet the differences found in the appearance of the brain in different cases were clearly associated with differences in age, and not with causes of death. On this whole question more data are needed. Exact measurements of the correlation between skull capacity and brain-weight are much to be desired. We also lack definite biometrical evidence regarding the effect of morbid conditions on the weight of the brain. The evidence at present available seems to lead to the conclusion here indicated.

On the other hand, it can hardly be maintained that natural selection has acted on the size of the brain to the degree that it has on skeletal structures. The brain, in this respect, comes nearer to the organs included in our most variable group. So that, on the one hand with a less marked dependence of the measurement on the previous metabolic condition of the organism than is found in the most variable group of organs and characters, and on the other hand, with a less stringent selection with reference to size as compared with the least variable group, an intermediate condition in variability for the brain is to be expected.

Of course, too much stress cannot be laid on this argument as to the relative variability of the characters of the human body in view of the meagreness of the data at present available. The data at hand, however, plainly suggest some such an explanation, and it is only as a tentative suggestion worthy of being kept in mind as further data are available that the matter has been developed here. To summarise; when a series of the various organs and characters of the body whose variation has been measured are arranged in the order of their relative variability, those characters falling at the most variable end of the series are those whose measured value is affected markedly by the previous general metabolic condition of the organism, and in which ability to function properly is not closely related to size of organ, and in which natural selection, if it has acted at all on the character, has not acted directly upon the thing measured. The opposite end of the series includes the least variable organs and characters, in which both the above mentioned conditions are reversed. Brain-weight and skull capacity occupy an intermediate condition both with reference to variability and the conditioning factors discussed.

Attention may be turned next to the question of the relative variability of the different races in respect to brain-weight. In the following scheme the races are arranged in descending order of mean brain-weight in the left-hand columns, and of variability (measured by the coefficient of variation) in the right-hand column. The lists are based on "total" series.

From these lists it would appear that as a general rule the higher the mean brain-weight is, the lower will be the variability. But it must be kept in mind that with our present series none of the differences in the variability columns is significant. Taking the extremes, Bavarians and Swedes for the males, and Bavarians and Bohemians for the females, the differences between the coefficients of variability with their probable errors are respectively $.526 \pm .217$ and $.958 \pm .337$.

Variation and Correlation in Brain-Weight

In these cases the difference is less than three times its probable error and cannot be considered as certainly significant. The lists are introduced merely to show the

♂		♀	
Mean	C. of V.	Mean	C. of V.
Bohemians Swedes Hessians Bavarians	Bavarians Hessians Bohemians Swedes	Bohemians Hessians Swedes Bavarians	Bavarians Hessians Swedes Bohemians

general trend of the results. It is possible that with much larger series of brain-weight statistics and consequently reduced probable errors some such relation as that just stated might be definitely proven.

For the sake of comparison and reference I include here tabular arrangements of the means and variabilities for the characters stature and age, made in the same way as that for brain-weight.

Stature.

♂		♀	
Mean	C. of V.	Mean	C. of V.
Swedes Bohemians Hessians Bavarians	Bohemians Hessians Swedes Bavarians	Swedes Bohemians Hessians Bavarians	Bohemians Hessians Swedes Bavarians

Age.

♂		♀	
Mean	S. D.	Mean	S. D.
Bohemians Swedes Bavarians Hessians	Hessians Bohemians Swedes Bavarians	Swedes Hessians Bavarians Bohemians	Bohemians Hessians Swedes Bavarians

Comparing the different characters the means seem to be entirely chaotic, but there is more regularity as regards the variabilities. The relative variabilities in stature and age for the different samples run parallel, with the exception of the Hessians and Bohemians in the male series. The samples which show the greatest variability in age of individuals included, also show the greatest variability in stature, and *vice versa*. This relation is, of course, to be expected, but the relation between

the brain-weight series and the other two is rather curious. There is no parallelism between the variability columns of the brain-weight series and the other two, but the variability columns of the stature series together with the females of the age series exactly agree (with the exception of the transposition of the Hessians and Swedes) with the columns of *means* of brain-weight. In other words in those series showing the greatest variability in stature (and in the females of age also) we have the highest mean brain-weight, and *vice versa*. No reason for this curious parallelism is apparent, and it may be purely accidental, but it seems worth noting.

The questions of the relative variability of the sexes in brain-weight and the racial differences as affected by sex will be discussed in a later section of the paper.

6. *On the Nature of the Frequency Distribution.*

In this section the variability in brain-weight will be discussed analytically, according to the methods and nomenclature of Pearson's fundamental memoir on Skew Variation* and its supplement†. My purpose in considering these curves analytically is not primarily that data may be furnished so that the material may be fitted with appropriate curves, but rather in order that definite knowledge may be had as to whether the variation in this character obeys the "normal" law of the deviation of errors. Both Miss Fawcett‡ and Macdonell§ have reached the conclusion that, for practical purposes at least, the majority of skull characters may be considered to conform to this law in their variation. It is of prime importance to determine in how far the same is true of the weight of the brain. Since this was my chief object in analyzing the data, I shall not at this time deal graphically with the curves, but instead shall merely present the chief analytical constants arranged in tabular form. Furthermore, from considerations of the time involved in computation, I have not determined the analytical constants for all the brain-weight frequency distributions given in this paper. Instead, after examining all the data, I decided to confine myself to the "total" series for both sexes of the four races.

The analytical constants for the selected series are exhibited in Table VIII. In the second column is given the number of brains on which the calculation in each case is based. The third column gives the unit in terms of which the second, third and fourth moments about the mean (μ_2 , μ_3 , and μ_4) are calculated: the next two columns give β_1 and $\sqrt{\beta_1}$, and the two following, β_2 and $3 - \beta_2$. Following this are given in order the "criterion" ($\kappa_1 = 2\beta_2 - 3\beta_1 - 6$)||, the mean, mode and skewness. The skewness was calculated from the moments directly by the formula

$$Sk = \frac{1}{2} \frac{\sqrt{\beta_1}(\beta_2 + 3)}{5\beta_2 - 6\beta_1 - 9}, \text{¶}$$

and from this the distance from mean to mode was obtained by multiplying by σ .

* *Phil. Trans.* Vol. 186, A, pp. 343—414.

† *Ibid.* Vol. 197, A, pp. 443—459.

‡ *Biometrika*, Vol. I, p. 443.

§ *Ibid.* Vol. III, p. 227.

|| *Phil. Trans.* Vol. 197, A, p. 444.

¶ Pearson, K.: "On the Mathematical Theory of Errors of Judgment and on the Personal Equation," *Phil. Trans.* Vol. 198, A, pp. 235—299. Page 277.

TABLE VIII.
Analytical Constants of Curves.
 Brain-weight.

Race and Series	No.	Unit	μ_2	μ_3	μ_4	β_1	$\sqrt{\beta_1}$	β_2	$3 - \beta_2$	Criterion	Mean	Mode	Skewness
Swede "Total" ♂	416	50 g.	4.5223	1.6292	57.18995	.0287	.1694	2.7964	.2036	-.4934	1400.481	1389.627	.1021
" " ♀	233	50 g.	4.0608	1.8441	51.1703	.0508	.2254	3.1031	-.1031	.0539	1252.682	1241.526	.1107
Hessian " ♂	475	50 g.	5.0783	-4.1458	86.8638	.1312	.3623	3.3682	-.3682	.3428	1391.737	1373.311	.1635
" " ♀	281	50 g.	4.1917	-.2601	49.8514	.0092	.0958	2.8372	.1628	-.3531	1259.875	1254.294	.0545
Bohemian " ♂	372	100 g.	1.2907	.5908	5.2300	.1623	.4029	3.1396	-.1396	-.2078	1454.839	1430.292	.2161
" " ♀	197	100 g.	.9365	.1033	2.5144	.01298	.1139	2.8671	.1329	-.3048	1310.914	1304.762	.0636
Bavarian " ♂	529	50 g.	4.8986	2.4919	79.2516	.0528	.2298	3.3026	-.3026	.4467	1363.185	1352.047	.1006
" " ♀	323	50 g.	4.1433	-.9391	77.7815	.0124	.1114	4.5408	-1.5408	3.0444	1220.356	1217.221	.0308
" " "Young" ♀	238	50 g.	3.3431	3.0329	45.6227	.2462	.4962	4.0820	-1.0820	2.4255	1235.504	1219.334	.1769

Considering first the *skewness*, it is seen to be in all the series positive, or the mean is greater than the mode. Further we note that in all cases the value is low. Whether the values can be considered significant however can only be determined by an examination of the probable errors. The formula for the probable error of the skewness is $\cdot67449 \sqrt{\frac{3}{2n}}$ *. The limiting values for this probable error for values of n ranging from 197 to 529 as in the present case are respectively $\cdot0589$ and $\cdot0359$. Having regard to the number of cases on which the calculations are based it appears that in six out of the nine cases tabulated the skewness can be regarded as certainly or probably insignificant. In all of these six cases the skewness is less than thrice its probable error, in two cases it about equals its probable error, and in one is less. The remaining three cases out of the total (skewness, $\cdot1635$, $\cdot2161$ and $\cdot1769$) are very probably or certainly significant. In general we may safely conclude, I think, that, *in the case of the weight of the brain, the distance from the mean to the mode will be very small. If the mean and mode do not coincide the mean will be greater than the mode.* This agrees with Miss Fawcett's† conclusion for the most important skull characters in the Naqada race. Macdonell‡ finds, however, that in the case of the English, considering the same skull characters, "if we were to draw the curves, the mean would be found in half the number of the curves to be less, and in the other half to be greater than the mode." In neither brain-weight nor skull series does there appear to be any definite preponderance in the value of the skewness of one sex over the other.

We may turn now to the other constants, which are of most significance in determining whether the distribution may be considered normal within the limits of error; viz., $\sqrt{\beta_1}$, β_2 , and the criterion. The probable error of $\sqrt{\beta_1}$ ($= \cdot67449 \sqrt{\frac{6}{n}}$) ranges in value for our series between $\cdot0718$ ($n=529$), and $\cdot1177$ ($n=197$); that of β_2 ($= \cdot67449 \sqrt{\frac{24}{n}}$) between $\cdot1437$ ($n=529$) and $\cdot2354$ ($n=197$); and that of the criterion ($= \cdot67449 \sqrt{\frac{96}{n}}$) between $\cdot2873$ ($n=529$) and $\cdot4708$ ($n=197$). Considering the probable errors of $\sqrt{\beta_1}$, it is seen at once that of the eight "total" series three give certainly insignificant values ($\cdot0958$, $\cdot1139$, $\cdot1113$) for $\sqrt{\beta_1}$; two others give values which are probably insignificant ($\cdot1694$, $\cdot2254$). One ($\cdot2298$) is probably significant; and the two remaining values ($\cdot3623$ and $\cdot4029$) are certainly significant. The Bavarian "young" ♀ series gives a certainly significant value for $\sqrt{\beta_1}$. Taking next the deviation of β_2 from 3 in comparison with the probable error of β_2 we see that in four cases ($3 - \beta_2 = -\cdot1031$, $\cdot1628$, $-\cdot1396$, $\cdot1329$) β_2 differs from 3 by an insignificant amount. In one case ($\cdot2036$) the difference is less than twice the probable error and hence may be considered

* The formulae for the probable errors of the analytical constants are given on p. 278 of Pearson's memoir on "The Mathematical Theory of Errors of Judgment," *loc. cit. supra*.

† *Loc. cit.* p. 443.

‡ *Biometrika*, Vol. III. p. 227.

as very probably insignificant. In two cases (.3682 and .3026) the difference is less than thrice the probable error and hence may be considered possibly, or even perhaps, probably insignificant. The Bavarian ♀ series, both "total" and "young," give certainly significant values for $3 - \beta_2$. Considering finally the criterion it is seen that in all cases except the two Bavarian ♀ the criterion differs from zero by a certainly or very probably insignificant amount. These two Bavarian ♀ series differed so greatly from the normal curve in most of the analytical constants that it was thought desirable to determine their position precisely by means of another constant κ_2^* . For the "total" series I found $\kappa_2 = .0032$, and for the "young" series $\kappa_2 = .0816$. By the scheme given by Pearson (*loc. cit.* p. 445) we see that the "total" series, when the probable errors of the constants are considered, comes very close to the condition demanding a curve of Type II ($\kappa_2 = 0$, $\beta_1 = 0$, β_2 not = 3). The "young" series clearly demands a curve of Type IV ($\kappa_2 > 0$ and < 1). The deviation of these Bavarian female curves from the normal type I believe to be due to an undue accumulation of individuals in one brain-weight class; viz., that from 1250—1300 gr. It seems altogether probable that some of the individuals which should have gone into the next higher class (represented in the "total" series by a frequency of only 26 as against 69 in the class next lower) have by some error been entered in Bischoff's lists with too low brain-weights. What the source of error was it is, of course, impossible now to determine. The abnormality of the Bavarian females has already been noted in the discussion of the means and variabilities. Leaving these two series out of account I think that on the whole we may safely conclude, as Miss Fawcett and Macdonell (*loc. cit.* p. 443, and p. 227 resp.) have for skull characters, that:

With series of brain weighings such as are considered in this paper we shall reach for most practical purposes adequate graphical representations of the frequency by using the normal curve of deviation: $y = y_0 e^{-x^2/2\sigma^2}$.

It should always be kept in mind, however, that our series, both on the brain-weight and skull sides, are too small to fix absolutely the normality or non-normality of the variation in these characters. Some of the distributions certainly differ from normality. The conclusion stated above is to be considered simply as a *practical* result, rather than as a theoretical generalization.

This result seems to be of considerable importance as indicating the worth of brain-weight statistics. It shows that such statistics justify careful study and analysis, and that, contrary to the statements of certain recent writers on the subject, there is no general fallacy inherent in the data themselves which renders abortive any attempt to reach through them the truth regarding the mass relations of the brain.

In order to test exactly how well the normal curve represents the data in a single case I have fitted the Swedish male "total" series with a normal curve. The frequency histogram and its fitted curve are shown graphically in the

* $\kappa_2 = \frac{\beta_1(\beta_2 + 3)^2}{4(\beta_2 - 3\beta_1)(2\beta_2 - 3\beta_1 - 6)}$, Pearson, *Phil. Trans.* Vol. 197, A, p. 444.

accompanying diagram. The unit of x is 50 grams. The scale of frequency at the left of the diagram gives y .

DIAGRAM I. Showing the distribution of variation in the brain-weight of adult Swedish Males.

The general equation $y = y_0 e^{-x^2/2\sigma^2}$, where in this case $y_0 = \frac{416}{\sigma \sqrt{2\pi}}$ and $\sigma = 2.1266$, becomes $y = 78.0401 e^{-.01106 x^2}$, with the origin at 1400.481. Applying Pearson's test of the goodness of fit*, and comparing *areas* instead of mid-ordinates, as is necessary where the number of frequency groups is so small, we get the results shown in the accompanying table. The table gives the observed frequencies (m_r'),

Grams of brain-weight	Observed	Calculated	$\frac{(m_r - m_r')^2}{m_r}$
Under 1100	0	.981	.981
1100—1150	1	2.9	1.24
1150—1200	10	8.5	.26
1200—1250	21	20.3	.02
1250—1300	44	39.0	.64
1300—1350	53	60.4	.91
1350—1400	86	75.2	1.55
1400—1450	72	75.3	.14
1450—1500	60	60.8	.01
1500—1550	28	39.4	3.29
1550—1600	25	20.6	.94
1600—1650	12	8.7	1.25
1650—1700	3	2.9	.003
1700—1750	1	.8	.05
1750 and over	0	.036	.036
Totals	416	415.817	11.320

* *Phil. Mag.* Vol. L. pp. 157—175.

the calculated frequencies (m_r), and the ratio of the squared difference between the two to the calculated $\left(\frac{(m_r - m_r')^2}{m_r}\right)$.

Here n' the number of frequency groups is 15 and $\chi^2 = 11.32$. From Elderton's Tables* the value of P may be obtained. With $n' = 15$ and $\chi^2 = 11$ the value of P as given in the table is .686036. Or, expressed in words, if the brain-weight of Swedish males obeyed the "normal" distribution of frequencies we should expect to get a greater divergence between theory and observation in roughly 65 out of every 100 trials when the trials were based on random samples of 416 individuals each. In other words, the fit may be considered very fair, and certainly entirely satisfactory for all practical purposes.

7. *The Correlation of Brain-weight with other Characters.*

In the introductory portion of this paper it was stated that one of the chief objects for which the work was undertaken was to measure exactly the degree and nature of the association between brain-weight and other characters in man. All workers on the subject have realized the importance of such determinations and numerous attempts have been made to arrive at them. The methods used, however, have not been such as to lead to definite and sound conclusions. These methods have in the main consisted in tabulating the mean brain-weights for various groupings of the other characters under consideration. In this way it can of course be determined whether there is any shift of the mean as the other character changes. Further than this one cannot go. Besides, in this method there lurk numerous pitfalls unless one uses it with a clear understanding of some of the fundamentals of statistical science. Different results can be obtained as the material is differently grouped. Hence, it is not strange that we find conservative anatomists making only very general statements as to the correlation of brain-weight with other characters, and, in those cases where an attempt at greater precision of statement is made, considerable difference of opinion as to what conclusions shall be drawn from the data. What are wanted in the case are not simply inspections and general "appreciations" of tabular lists of brain-weighings, or of ratios and indices, or even of correlation tables or regression lines but instead definitely determined coefficients of correlation with their probable errors. With these we can get in given cases precise statements of the degree of correlation between different characters.

It would of course be highly desirable to measure the correlation between the weight of the brain and a great variety of other organs and characters of the body. Such characters will at once suggest themselves to anyone interested in the problems of correlation. For instance, aside from age, stature and body-weight for which material is available, there are the whole range of skull characters; the

* *Biometrika*, Vol. I. p. 161.

weights of the various viscera; the weight and volume of the spinal cord; characters of the muscular system, etc. A study of the correlation between any or all of these characters and the weight of the brain would be most interesting. But, unfortunately, material for such study cannot be had. Brain-weight statistics usually provide data for but few other characters; in the majority of cases only sex, age and stature. In two of the series used in this work, viz., the Swedish and Hessian, this was the case. For these two groups I have determined all possible correlations for both sexes, and for two age groupings ("young" and "total"). This gives as the pairs of characters, (a) brain-weight and stature, (b) brain-weight and age, (c) stature and age. Bischoff's Bavarian material furnished in addition to the above, data on the body-weight. The following correlations have been determined for this material: (a) brain-weight and age ("total" and "young"), (b) brain-weight and stature ("total"), (c) brain-weight and body-weight ("total"), (d) body-weight and stature ("total"). In the case of the Bohemian material data were furnished from which the correlation between skull length and skull breadth could be determined so that for this group I have been able to calculate coefficients of correlation for the following pairs of characters: (a) brain-weight and stature ("young"), (b) brain-weight and age ("total"), (c) brain-weight and skull length ("young"), (d) brain-weight and skull breadth ("young"), (e) skull length and skull breadth ("young"). In Table IX are exhibited the coefficients of correlation together with their probable errors. The correlation tables from which the coefficients were calculated are given in the appendix to this paper, Tables 1 to 44. References are given in Table IX telling for each coefficient the original table from which it was calculated. The coefficients of correlation were determined from the usual Bravais formula according to which the coefficient of correlation

$$r = \frac{S(xy)}{N\sigma_1\sigma_2},$$

where x and y are deviations from the means of the two correlated characters and σ_1 and σ_2 are the respective standard deviations; the usual* method of evaluating r from the above equation was used.

The most striking fact of a general nature shown by this table is the generally low degree of correlation which exists between the weight of the brain and other characters. The coefficients run noticeably lower even than those of skull characters (cf. Macdonell's Table V†) and very markedly below those between different characters of the long bones‡. On the other hand our brain-weight correlations give values of the same general order of magnitude as those found by Greenwood§ for various abdominal and thoracic viscera. Attention may be called

* Yule: *Jour. Roy. Stat. Soc.* Vol. LX. Part iv. pp. 1—44 (Reprint).

† *Biometrika*, Vol. III. p. 232.

‡ Lee and Pearson: *Phil. Trans.* Vol. 196, A, pp. 228, 229.

§ *Loc. cit.* p. 19 above.

TABLE IX.
Brain-weight. Correlations.

Character and Series	Swedes						Hessians					
	♂			♀			♂			♀		
	No.		Table	No.		Table	No.		Table	No.		Table
Brain-weight and Stature (Total) ...	416	$\cdot 1830 \pm \cdot 0320$	1	233	$\cdot 3490 \pm \cdot 0388$	2	475	$\cdot 1823 \pm \cdot 0299$	13	281	$\cdot 1828 \pm \cdot 0389$	14
" " " " (Young) ...	262	$\cdot 1796 \pm \cdot 0403$	3	127	$\cdot 3390 \pm \cdot 0530$	4	291	$\cdot 1741 \pm \cdot 0383$	15	173	$\cdot 1809 \pm \cdot 0496$	16
Brain-weight and Age (Total) ...	416	$-\cdot 2493 \pm \cdot 0310$	5	233	$-\cdot 2336 \pm \cdot 0418$	6	475	$-\cdot 1673 \pm \cdot 0300$	17	281	$-\cdot 3598 \pm \cdot 0350$	18
" " " " (Young) ...	262	$-\cdot 1705 \pm \cdot 0405$	7	127	$-\cdot 1512 \pm \cdot 0585$	8	291	$-\cdot 0750 \pm \cdot 0393$	19	173	$-\cdot 1650 \pm \cdot 0499$	20
Stature and Age (Total) ...	416	$-\cdot 1620 \pm \cdot 0322$	9	233	$-\cdot 2279 \pm \cdot 0419$	10	475	$\cdot 0481 \pm \cdot 0308$	21	281	$-\cdot 0915 \pm \cdot 0399$	22
" " " (Young) ...	262	$-\cdot 2549 \pm \cdot 0390$	11	127	$-\cdot 2120 \pm \cdot 0572$	12	291	$\cdot 2102 \pm \cdot 0378$	23	173	$-\cdot 0474 \pm \cdot 0512$	24
Character and Series	Bohemians						Bavarians					
	♂			♀			♂			♀		
	No.		Table	No.		Table	No.		Table	No.		Table
Brain-weight and Stature (Total) ...							365	$\cdot 1664 \pm \cdot 0343$	35	241	$\cdot 2236 \pm \cdot 0413$	36
" " " " (Young) ...	266	$\cdot 2034 \pm \cdot 0397$	25	133	$\cdot 2168 \pm \cdot 0557$	26						
Brain-weight and Age (Total) ...	372	$-\cdot 2045 \pm \cdot 0335$	27	197	$-\cdot 2558 \pm \cdot 0449$	28	529	$-\cdot 1225 \pm \cdot 0290$	37	323	$-\cdot 2405 \pm \cdot 0354$	38
" " " " (Young) ...							365	$-\cdot 0100 \pm \cdot 0353$	39	238	$\cdot 0114 \pm \cdot 0412$	40
Brain-weight and Skull Length (Young)	299	$\cdot 5482 \pm \cdot 0273$	29	159	$\cdot 3604 \pm \cdot 0465$	30						
" " " " Skull Breadth (Young)	299	$\cdot 4655 \pm \cdot 0306$	31	159	$\cdot 5041 \pm \cdot 0399$	32						
Brain-weight and Body-weight (Total) ...							365	$\cdot 1671 \pm \cdot 0343$	41	241	$\cdot 2260 \pm \cdot 0412$	42
Skull Length and Skull Breadth (Young)	299	$\cdot 4006 \pm \cdot 0327$	33	159	$\cdot 1954 \pm \cdot 0514$	34						
Body-weight and Stature (Total) ...							365	$\cdot 3962 \pm \cdot 0298$	43	241	$\cdot 4334 \pm \cdot 0352$	44

here to the general uniformity of the correlations for the same characters in different series. All the brain-weight and stature correlations are seen to be positive, while with a single exception (Bavarian female "young" series) all the correlations of brain-weight with age are negative. The coefficients are generally lower for the "young" than for the "total" series, as is to be expected. In the case of the correlation of brain-weight with age, some of the coefficients for the "young" series are evidently insignificant in comparison with their probable errors. The correlations between stature and age are negative with the exception of the Hessian male series. The positive sign in these series arises from the fact that in this material the age class 15 to 20 was included. All growth in stature has not stopped at age 20, and as a consequence there are included in the tables (21 and 23) five individuals of unusually small stature and low age. These serve to change the sign of the coefficients. Their greater effect in the "young" series is apparent. The detailed discussion of the various brain-weight correlations and the regressions based on them I propose to take up in separate sections of the paper now to follow.

8. *Brain-weight and Sex.*

All brain-weight statistics show that the brain of the male is absolutely heavier than that of the female. In the series here discussed the absolute differences in mean brain-weight between males and females are as follows:

	Male mean—Female mean	
	"Total" series	"Young" series
Swedes ...	147·8	145·8
Bohemians ...	143·9	146·2
Bavarians ...	142·8	133·6
Hessians ...	131·9	125·6

From this table the following points are to be noted:

(a) Considering the size of the probable errors involved it is evident at once that the *absolute* difference is sensibly the same for all four races. Taking the extremes of the "total" column the difference between the Swede and Hessian sex differences is 15·9 with a probable error of $\pm 7·9$, or in other words the difference is almost exactly twice its probable error and cannot be considered certainly significant. The "young" series points to the same conclusion. So then, Weisbach's law for stature that the greatest sex differences occur in those races having the highest mean stature, does not appear to hold for brain-weight, so far as absolute differences are concerned.

(b) The absolute sex differences are sensibly the same for both age groupings. We may conclude then, that whatever changes occur in the weight of the brain with advancing age act in such a way as to leave the absolute sex difference unchanged.

These absolute differences may be converted into relative differences by expressing them as percentages of the ♂ and ♀ means. When so expressed they take the following form :

Sex Differences in Relation to Means.

Race	"Total" series		"Young" series	
	Percentage of ♂ mean	Percentage of ♀ mean	Percentage of ♂ mean	Percentage of ♀ mean
Swedes ...	10·6 %	11·8 %	10·3 %	11·5 %
Bavarians ...	10·5 %	11·7 %	9·8 %	10·8 %
Bohemians ...	9·9 %	10·97 %	10·0 %	11·1 %
Hessians ...	9·5 %	10·5 %	8·9 %	9·8 %

The relative differences confirm the conclusions reached from the examination of absolute differences. The result that the changes which take place in the weight of the brain during adult life affect both sexes to an equal degree relatively seems to be of some importance. It implies that the factors which bring about the gradual lowering in the weight of the brain with advancing age are organic in a strict sense, and not dependent on environmental conditions.

The same thing is shown if the relative differences expressed in another way, namely by taking the ratio of male to female mean, are examined. For our series these ratios are as follows :

Sex Ratios. Means. Brain-weight.

Race	"Total" series	"Young" series
Swedes ...	1·118	1·115
Bavarians ...	1·117	1·108
Bohemians ...	1·110	1·111
Hessians ...	1·105	1·098

The sex ratios for a number of other characters are given in the following table for comparison. The values in this table are taken from a table in Pearson's *Chances of Death**.

* Vol. I. p. 374.

Sex Ratios. Means. Various Physical Characters.

Organ or Character	Sex Ratio
Body weight, Babies	1·034
" " Children	1·038
" " Adults	1·193
Weight of Vital Organs	1·130
Stature, Children	1·007
" Adults	1·077
Height, Sitting	1·032
Long Bones	1·086
Chest Girth	1·024
Squeeze of Hands	1·207
Keeness of Sight and Touch ...	1·061
Skull Capacity	1·124
" Circumference	1·042
Cephalic Index	·997
Head Index	·995
Profile Angle	·994
Alveolar Angle	·994
Nose and Palate	1·013

We may turn next to the question of the relative variability of the sexes in respect to brain-weight. Pearson* found that in the case of the English, the female showed "slightly more" variability than males; the French data which he worked over gave sensibly equal variabilities for the sexes, as did also Bischoff's Bavarian data. In the following table are shown the differences between the male and female coefficients of variation with the probable errors of the differences. The values tabulated are the male minus the female constant in each case.

Relative Variability of the Sexes. Male - Female.

Race	Coefficient of Variation	
	"Total" series	"Young" series
Bohemians ...	·427 ± ·320	·740 ± ·375
Hessians ...	- ·029 ± ·293	- ·036 ± ·366
Bavarians ...	- ·222 ± ·254	·546 ± ·305
Swedes ...	- ·451 ± ·310	- ·600 ± ·422

In three cases out of the eight the male has a larger coefficient of variation, but in no instance can the differences between male and female coefficients be considered significant when compared with the probable errors. In only one case (Bohemian "young" series) does the difference approach closely to a value even twice as great as its probable error. Therefore we must conclude that, so far as the series here considered are concerned, there is no significant difference between

* *Chances of Death*, Vol. I. pp. 321, 322.

males and females in respect to variability in the weight of the brain. In view of the general reliability, from a statistical standpoint, which has been previously demonstrated to exist in the material on which this work is based, it seems not unreasonable to predict that it will be found that equal variability of the sexes in brain-weight holds generally.

Another problem which presents itself in this connection is as to how much of the observed difference between males and females in brain-weight is to be accounted for by the fact that the male body is in general larger than the female. In other words, would a group of females of the same stature and age, say, as a given group of males have the same brain-weight? It is possible to reach a general solution of this problem by the use of characteristic equations based on the correlations and regressions. I propose now to discuss this question by this method. Of course, the prediction may be made by characteristic equations in either direction; i.e., we may predict the probable brain-weight of a group of males having other characters the same as in a given group of females, or we can predict the probable brain-weight of a group of females having the characters the same as in a given group of males. In the former case characteristic equations based on the male data would be used, in the latter the equations would be those deduced from female data. We may consider first the characters, age, and stature. In the following tables are given (a) the probable brain-weights of a group of individuals of the sex indicated, as calculated from the characteristic equation referred to in the last column of the table; (b) the observed brain-weights of a group of the opposite sex having for the other characters the mean values used in the characteristic equation in calculating (a); (c) the difference between (a) and (b); (d) a reference to the equation from which (a) is calculated.

TABLE X.

Probable Female Brain-weight with Stature and Age equal to Observed Male.

Race	Predicted female brain-weight	Observed male brain-weight	Difference	Equation
Hessian (Total) ...	1287·963	1391·737	103·774	25
„ (Young) ...	1308·941	1405·756	96·815	26
Swede (Total) ...	1307·340	1400·481	93·141	21
„ (Young) ...	1319·783	1415·267	95·484	22

The mean difference here is 97·304. The mean observed difference between male and female without any allowance for stature and age is 137·8 for the same races. So then the differences in stature and age between the males and females in our Swedish and Hessian samples account for only 40·5 gr. or about 29 per cent. of the observed difference in mean brain-weight between the sexes.

Let us now proceed to the reversed prediction, and find the probable brain-weights of a group of males having the same stature and age as the means for

these characters in the Hessian and Swedish females. The results are shown in Table XI, which is arranged in the same manner as the preceding table.

TABLE XI.

Probable Male Brain-weight with Stature and Age equal to Observed Female.

Race	Predicted male brain-weight	Observed female brain-weight	Difference	Equation
Hessian (Total) ...	1357·591	1259·875	97·716	23
„ (Young) ...	1369·431	1280·202	89·229	24
Swede (Total) ...	1370·543	1252·682	117·861	19
„ (Young) ...	1391·624	1269·488	122·136	20

The mean difference here is 106·736, or in other words we reach essentially the same result as before. The general conclusion up to this point then is that there is a difference in the mean brain-weight between the sexes of roughly 100 gr. after allowance has been made for stature and age differences by taking the mean brain-weight of an array of individuals of one sex having for type of stature and age the respective means of these characters observed in the other sex. Differences in stature and age account for less than one-third of the observed sex difference in brain-weight.

We may next determine what part of the observed sex difference in brain-weight is to be accounted for by differences in skull length and breadth. Here only one race, the Bohemian, can be used on account of lack of material. Let us examine the effect on the mean brain-weight of selecting a group of individuals of one sex having the same mean skull length and skull breadth as the opposite sex. Making the designated selection first from the males and then from the females we have the results shown in Table XII.

TABLE XII.

Probable Male Brain-weight with Mean Skull Length and Skull Breadth equal to the Observed Female.

Race	Predicted male brain-weight	Observed female brain-weight	Difference	Equation
Bohemian ...	1395·631	1310·914	84·717	35

Probable Female Brain-weight with Mean Skull Length and Skull Breadth equal to the Observed Male.

Race	Predicted female brain-weight	Observed male brain-weight	Difference	Equation
Bohemian ...	1389·736	1454·839	65·103	36

The mean of the two differences is 74.910, while the observed difference between male and female mean brain-weights in the Bohemian "skull" series is 142.014, or in other words by selecting from either sex individuals with mean skull length and skull breadth equal to those found in the opposite sex, we are able to reduce the sex difference in mean brain-weight by about 67 grams, or 47 %. This result is of considerable interest. We can come nearer to the brain-weight of one sex by selecting skull length and breadth to the means of that sex than we can by selecting stature and age, but still not a great deal nearer. We should on general grounds expect that aside from skull capacity, skull length and skull breadth would be the two characters whose selection would indirectly modify brain-weight the most. Admitting this to be the case there still remains a considerable difference to be accounted for. It is interesting to note that the sexes are brought nearer together in brain-weight when males are selected than when the selection is from the females. This is explained by the fact that the brain-weight is somewhat more highly correlated with the skull characters in the males in our series.

Finally, we may examine the effect of a selection of stature and body-weight on the sex difference in brain-weight. The material here comes from the Bavarian series, and the prediction is made in the same way as in the other cases; viz., by selecting males with mean stature and body-weight equal to the female means and *vice versa*, and determining the mean brain-weight of the selected groups. The results are shown in Table XIII.

TABLE XIII.

Probable Male Brain-weight with Mean Stature and Body-weight equal to the Observed Female.

Race	Predicted male brain-weight	Observed female brain-weight	Difference	Equation
Bavarian ...	1321.496	1218.776	102.720	29

Probable Female Brain-weight with Mean Stature and Body-weight equal to the Observed Male.

Race	Predicted female brain-weight	Observed male brain-weight	Difference	Equation
Bavarian ...	1261.298	1357.466	96.168	30

Here the better result is obtained by selecting from the females on account of the higher correlation between brain-weight and body-weight and brain-weight and stature in this sex. The mean of the two differences is 99.444, and the observed sex difference in the case is 138.690 gr. So then the differences between

the sexes in body-weight and stature account for 39.246 gr. or 28 % of the observed difference in mean brain-weights. In other words, by selecting individuals on the basis of body-weight and stature alone we shall produce about the same degree of change in the mean brain-weight as by selecting on the basis of stature and age alone.

Taking all the results together we reach the general conclusion that the difference between the sexes in mean brain-weight is only in part to be accounted for by differences in other bodily characters. While in general it is true that a small body has a brain of low weight, yet in order for the observed difference in mean brain-weight in men and women to be due to this factor alone either the women ought to have very much smaller bodies than they actually possess, or the men ought to have larger bodies, or both sexes ought to be different from what they actually are in size of body in the directions indicated. Of course it is very easy to say by way of speculation that the smaller brain of woman is due to the fact that the female human organism is subjected to less strenuous demands along the lines of motor and intellectual activity than the male. But such speculation leads to nothing on account of our lack of definite scientific evidence as to the degree of correlation between the weight of the brain and amount and intensity of psychic activity.

One other question remains to be considered in connection with the relation of brain-weight to sex. Does either sex show any considerably higher degree of correlation between brain-weight and other characters than the other? Table IX furnishes data on this point. With the exception of the Swedish brain-weight and age correlations and the brain-weight and skull-length correlations it is seen that the female coefficients are uniformly larger than the male. The differences are in many of the cases not significant in comparison with their probable errors but the general tendency towards higher correlations in the females is clearly evident. The meaning of this tendency is in this case difficult to conjecture. It falls in line with the result which has been pointed out by Lee and Pearson in several papers*, viz., that for physical characters generally women usually show a higher degree of correlation than men, in civilized races.

9. *Brain-weight, Age and Stature.*

The coefficients of correlation between brain-weight and age and stature respectively have already been given in Table IX, but before proceeding further in the discussion of their significance it is necessary to determine whether the regressions are linear. One might on general grounds expect the brain-weight and age correlations to be skew, since this is generally the case with growth correlations where one of the variables is age and the other the absolute magnitude of some organ or character. If in any case the correlation turns out to be skew, it of course greatly complicates the problem.

The method of analysis which I have followed in determining the degree of

* E.g., "On the Relative Variability and Correlation in Civilized and Uncivilized Races," *Roy. Soc. Proc.* Vol. LXXI. pp. 343—357.

approach to linearity of the regressions is that given by Pearson*. The two constants which are of the greatest significance here are, (a) the mean square deviation of the means of the arrays from the regression line, Σ_M^2 , and (b) a constant η , called the correlation ratio, giving the mean reduction in variability of an array as compared with the whole population. Evidently

$$\Sigma_M^2 = \sigma_M^2 - r^2 \sigma^2 \dots\dots\dots(i),$$

and

$$\eta = \frac{\sigma_M}{\sigma} \dots\dots\dots(ii),$$

$$\text{whence by simple substitution } \Sigma_M^2 = (\eta^2 - r^2) \sigma^2 \dots\dots\dots(iii),$$

where in these equations σ is, as usual, the standard deviation of the variates about the mean for the whole population, r is the coefficient of correlation between the two variables concerned, and σ_M is the standard deviation of the means of the arrays about the mean of these means. The deviation of Σ_M from zero, and of η from r , measure the deviation of the system from linearity†.

I propose to discuss the relation of brain-weight first to age alone, then to stature alone, and finally to both age and stature together.

In Table XIV are exhibited the values of Σ_M and η for the correlations between brain-weight and age discussed in this paper. In calculating σ_M from which to obtain η according to the relation given above, in this and all other cases the means of the arrays were weighted with the number of cases on which they were based. This procedure of course gave the mean of the means of the arrays the same value as the general population mean calculated from the elemental frequency distribution.

TABLE XIV.

Analytical Constants for Linearity of Regression. Brain-weight and Age.

Race and Series	r		η		Σ_M	
	♂	♀	♂	♀	♂	♀
Swedish (Total) ...	-.2493 ± .0310	-.2336 ± .0418	.2876	.2770	.1434 σ	.1489 σ
„ (Young)...	-.1705 ± .0405	-.1512 ± .0585	.2251	.2143	.1469 σ	.1519 σ
Hessian (Total) ...	-.1673 ± .0300	-.3598 ± .0350	.2002	.3864	.10996 σ	.1409 σ
„ (Young)...	-.0750 ± .0393	-.1650 ± .0499	.1411	.1961	.1195 σ	.1060 σ
Bavarian (Total) ...	-.1225 ± .0290	-.2405 ± .0354	.1962	.3481	.1533 σ	.2517 σ
„ (Young)...	-.0100 ± .0353	-.0114 ± .0412	.0676	.1958	.0669 σ	.1955 σ
Bohemian (Total) ...	-.2045 ± .0335	-.2558 ± .0449	.2441	.3033	.1333 σ	.1628 σ

* *Roy. Soc. Proc.* Vol. LXXI, pp. 303—313, especially the footnote, pp. 303, 304. Since the above was written a very full treatment of the whole subject of skew correlation and non-linear regression by Prof. Pearson has appeared as “Mathematical Contributions to the Theory of Evolution, XIV.” *Drapers’ Company Research Memoirs*, Biometric Series II. 1905.

† Of course the deviation of η from r must be considered numerically simply, because η is necessarily a positive quantity from (ii) above, since neither σ_M nor σ can be negative. If the difference between η and r were taken with reference to sign in cases where r is minus, an altogether false notion of the degree of departure of the regression from strict linearity would be obtained. The degree of this departure will always, of course, be immediately given by Σ_M whatever the sign of r .

It is seen at once that η differs from r and Σ_M from zero in all cases. This, of course, implies departure of the system from linearity. But evidently deviations of a system from linearity may be due to either one or both of two causes. Either, on the one hand, the system may be truly non-linear, in which event the means of the arrays will be fitted better by some curve than by a straight line, or, on the other hand, the points fixed by the means of the arrays may not lie exactly on a straight line and still no curve will represent the relationship between the two variables concerned better than a straight line so drawn that the mean square of the deviations of the points from the line is a minimum. In the first case we have true non-linearity of the regression, while in the second the deviation from linearity is due to the errors of random sampling, and it might reasonably be expected that if the whole population could be studied the regression would become strictly linear. Now evidently in both these cases η will differ from r and Σ_M from zero, so that recourse must be had to some further method in order to determine into which class a given case falls. Two such methods immediately suggest themselves: one, to examine the probable errors involved, the other, to inspect the fitted regression line.

An examination of Table XIV makes it immediately evident that the differences between η and r (without regard to sign) give values of the same order of magnitude as the probable errors of r . In only one case is this difference as great as three times the probable error of r , and in the great majority of cases it does not approach such a value*. So then it seems probable that in our series the regression of brain-weight on age is linear within the errors arising from random sampling. The approach to linearity is sensibly the same both for the whole period of adult life and for the younger half of this period.

In order to bring out the facts graphically I have had prepared a series of diagrams showing the regression lines for brain-weight on age. For the sake of economizing space, and since there is essential agreement between the different series with respect to η , it was decided not to publish all the regression diagrams. I have chosen for representation here the regression lines for the Swedish and the Hessian data. These are shown in Diagrams II to IX.

DIAGRAM II. Probable Brain-weight for given Age.
Swedish & Total.

[* The proper test is the probable error of $\eta \sim r$, which we hope will shortly be published. Ed.]

Variation and Correlation in Brain-Weight

DIAGRAM III. Probable Brain-weight for given Age.

Swedish ♀ Total.

DIAGRAM IV. Probable Brain-weight for given Age.

Hessian ♂ Total.

DIAGRAM V. Probable Brain-weight with given Age.

Hessian ♀ Total.

DIAGRAM VI. Probable Brain-weight with given Age.
Swedish ♂ Young.

DIAGRAM VII. Probable Brain-weight with given Age.
Swedish ♀ Young.

DIAGRAM VIII. Probable Brain-weight for given Age.
Hessian ♂ Young.

Variation and Correlation in Brain-Weight

DIAGRAM IX. Probable Brain-weight for given Age.

Hessian ♀ Young.

These diagrams show clearly, I think, that the regression of brain-weight on age in these cases is sensibly linear within the ages 15 to 80, so far as can be judged on the material available. The regression diagrams for the other two racial groups show the same relation. Obviously no simple curve will represent the systems of points shown in these diagrams II to IX better than the straight line does. So then, until we have very much larger samples of material to work with, we shall be justified in assuming for practical purposes linearity of regression between brain-weight and age, and in considering the deviations of the means of the arrays from the regression line to be due to errors incident to sampling in lots of less than 500 individuals.

The equations to the regression lines for these diagrams may now be given. For convenience in practical use I have put these equations in the form of "characteristic" equations. The significance of the letters used is as follows: W denotes the probable brain-weight in grams of an array of individuals of age type A or a . The ages included by A are 15 or 20 to 80; by a 15 or 20 to 50, or in other words the equations containing A are deduced from the "total" series and those containing a from the "young" series. Σ is the standard deviation of the array having the probable W as its mean.

(1)	Swedish ♂	$W=1487.783-1.939 A$,	$\Sigma=102.972$
(2)	" ♂	$W=1501.411-2.372 a$,	$\Sigma=107.582$
(3)	" ♀	$W=1326.475-1.549 A$,	$\Sigma=97.969$
(4)	" ♀	$W=1340.438-1.988 a$,	$\Sigma=104.329$
(5)	Hessian ♂	$W=1439.734-1.119 A$,	$\Sigma=111.087$
(6)	" ♂	$W=1432.497-.847 a$,	$\Sigma=111.014$
(7)	" ♀	$W=1361.067-2.259 A$,	$\Sigma=95.512$
(8)	" ♀	$W=1339.298-1.735 a$,	$\Sigma=100.445$

The foregoing constants bring out a number of interesting and important facts regarding the relation of brain-weight to age. In the first place it is clear that diminution in brain-weight with advancing years takes place very slowly. In 10 years the Swedish males lose 19.39 grs. and the Hessian males 11.19 grs.*

* In order to economize space I have not tabulated the regression coefficients separately. It will be understood of course by anyone wishing to refer to or use these regression coefficients that the number prefixing a letter in the second member of any of the characteristic equations 1 to 36 is the regression coefficient (either gross or partial) of brain-weight on the character indicated by the letter.

These are comparatively speaking slight changes, amounting respectively to 1.3% and .8% of the mean brain-weight for the whole adult period. In the same length of time (10 years) males lose an average of .34" in stature or approximately .5% of the mean stature*. The diminution in brain-weight seems thus to be relatively somewhat more rapid than the diminution in stature.

The fact that the regression is linear implies that this diminution of brain-weight with advancing age so far as can be judged from the material here discussed is sensibly equally distributed over the whole adult period. To be sure the slope of the lines is in all but one case (the Swedes) less when the individuals between 20 and 50 are treated separately, but the difference is a small one when the probable error is considered (cf. Table IX or XIV). Splitting the material up in this way of course greatly reduces the already statistically small series, so that the probable errors of the coefficients of correlation for the "young" series become large. It is significant, however, that with a single exception (the otherwise abnormal Bavarian female series) all the coefficients of correlation between brain-weight and age for the "young" series are negative. The evidence presented by each of the four series here discussed, which are representative and have been shown to be statistically trustworthy, and which if not as large as might be desired by the statistician are among the largest ever collected by the neurologist, is mutually accordant, and leads to but one conclusion: namely, that *after age 15—20 there is a steady though very gradual diminution in the weight of the brain with advancing age*. This conclusion I have emphasized because it is not in agreement with that reached by some eminent neurological authorities. I would further emphasize the fact that the conclusion is by no means final in the mind of the biometrician. It simply marks the point to which the material at present available leads. Very much larger series of brain-weighings are needed before the precise form of the regression can be finally determined. But the fact that four distinct series of fair length taken by different observers on different races lead to such closely accordant results as those shown in Table XIV may be taken as very strong presumptive evidence of the essential correctness of the conclusion reached.

It is noteworthy that there is no tendency towards more rapid diminution on brain-weight after age 50 to 60. The rate of diminution shows no such marked changes at this time as has been maintained to occur by many of the workers on the subject.

With the exception of the Swedish series the females in all cases show a higher correlation between brain-weight and age than the males. This difference seems in the case of the Hessians and Bavarians (total series) to be probably significant. According to Powys' (*loc. cit.*) figures the slope of the regression line between stature and age is slightly steeper for the females. It is difficult to assign any reason for this greater correlation between brain-weight and age in

* Powys, A. O.: "Data for the Problem of Evolution in Man. Anthropometric Data from Australia," *Biometrika*, Vol. I. pp. 30—49.

the female. It has been shown above that there is in general no significant difference between the sexes in respect to variability in brain-weight, so that the usual formula of "low variation and high correlation" connoting stability of type does not hold in this case. It is possible that we have here an expression in a particular case of a greater general "evenness" in the females of the bodily changes accompanying increasing age, which in turn might be due to the generally more even environmental conditions to which women are subjected. It is noteworthy in this connection that the correlation in respect to duration of life is generally higher between pairs of female relatives than between pairs of male relatives*.

The linearity of the regression of brain-weight on age is of interest as possibly indicating a fundamental difference in the modes of action of the biological processes of growth on the one hand and senescence on the other. When growth in absolute magnitude of a character is plotted on a base line of age the result is usually a curved line (cf. for example the 12—25 portion of Powys' stature curve, *loc. cit.*), which implies, of course, that the amount of increment in the character in question is not the same for each unit of time. On the other hand in the case of decrease of brain-weight and stature with advancing age the decrement seems to be practically uniform for each unit of time. If these relations should prove to be generally true they would furnish a very interesting field for further study and analysis.

Turning now to the relation of brain-weight to stature, we have in Table XV the values of r , η and Σ_M , for all the brain-weight and stature correlations.

TABLE XV.
Linearity of Regression. Brain-weight and Stature.

Race and Series	r		η		Σ_M	
	♂	♀	♂	♀	♂	♀
Swedish (Total) ...	.1830 ± .0320	.3490 ± .0388	.2439	.3847	.1612 σ	.1618 σ
" (Young)...	.1796 ± .0403	.3390 ± .0530	.2837	.4738	.2196 σ	.3310 σ
Hessian (Total) ...	.1823 ± .0299	.1828 ± .0389	.2864	.3215	.2209 σ	.2645 σ
" (Young)...	.1741 ± .0383	.1809 ± .0496	.2714	.3807	.2082 σ	.3350 σ
Bavarian (Total) ...	.1664 ± .0343	.2236 ± .0413	.2262	.3270	.1532 σ	.2386 σ
Bohemian (Young)...	.2034 ± .0397	.2168 ± .0557	.2419	.3591	.1309 σ	.2863 σ

Again, the values of η and Σ_M are seen to diverge considerably from r and 0 respectively. It is clear that on the whole the regression of brain-weight on stature approaches less closely to linearity than does the regression of brain-weight on age. This is, I think, a somewhat remarkable result, and one not likely to have been foreseen.

* Beeton and Pearson: *Biometrika*, Vol. I. p. 60.

In order to determine whether the departure of the regression from strict linearity is due simply to errors of sampling or to a fundamentally different law of relation between the two variables it is again necessary to have recourse to regression diagrams. I have selected eight diagrams which are fairly representative.

DIAGRAM X. Probable Brain-weight for given Stature.

Swedish ♂ Total.

DIAGRAM XI. Probable Brain-weight for given Stature.

Swedish ♀ Total.

DIAGRAM XII. Probable Brain-weight for given Stature.

Swedish ♂ Young.

Variation and Correlation in Brain-Weight

DIAGRAM XIII. Probable Brain-weight for given Stature.
Swedish ♀ Young.

DIAGRAM XIV. Probable Brain-weight for given Stature.
Hessian ♂ Total.

DIAGRAM XV. Probable Brain-weight for given Stature.
Hessian ♀ Total.

DIAGRAM XVI. Probable Brain-weight for given Stature.
Hessian ♂ Young.

DIAGRAM XVII. Probable Brain-weight for given Stature.
Hessian ♀ Young.

It is evident from these diagrams that a straight line represents the regression relation between brain-weight and stature better than any simple curve would. So that we are justified in concluding, as in the case of age, that until we have very much larger collections of data than are at present available we can do no better than proceed on the assumption that the regression of brain-weight on stature is linear. In fact, in these samples there is no evidence that there is any tendency towards anything but a linear relation between the two variables. The deviations of the means of the arrays from the regression line are only such as would reasonably be expected to arise when we deal with relatively small samples. In connection with all of the regression diagrams in this paper it should be kept in mind that the outlying points are based on single individuals, or at most only on comparatively few individuals. Hence deviations of these outlying points from the regression line have very little or no significance as regards the general trend of the results. In fact it would really be better if

the outlying points were left out entirely in the graphical representations. The non-biometrical reader should understand that each plotted point carries weight in proportion to the fraction which the number of individuals in the array on which it is based is of the total number of individuals. With this caution in mind the substantial linearity of the regression through the bulk of the observations, which alone are of importance, becomes evident.

The regression equations showing numerically the relation between brain-weight and stature, may now be given. In these equations W denotes the probable brain-weight of an array of individuals of mean stature S or s in centimetres. As before, the equations involving S are based on the "total" series, and those involving s on the "young" series. Σ is the standard deviation of the array having the probable mean brain-weight W .

(9)	Swedish	♂	$W=915.054+2.859S$,	$\Sigma=104.533$
(10)	"	♂	$W=919.374+2.914s$,	$\Sigma=107.405$
(11)	"	♀	$W=421.994+5.234S$,	$\Sigma=94.421$
(12)	"	♀	$W=451.643+5.121s$,	$\Sigma=99.294$
(13)	Hessian	♂	$W=913.592+2.857S$,	$\Sigma=110.787$
(14)	"	♂	$W=950.214+2.723s$,	$\Sigma=109.628$
(15)	"	♀	$W=834.624+2.714S$,	$\Sigma=100.643$
(16)	"	♀	$W=894.031+2.460s$,	$\Sigma=100.161$
(17)	Bavarian	♂	$W=836.667+3.127S$,	$\Sigma=118.452$
(18)	"	♀	$W=627.157+3.824s$,	$\Sigma=103.562$

We may now proceed to the general conclusions to be drawn from the data given above regarding the relation of brain-weight to stature. In the first place it is to be noted that the correlation coefficients between these two variables are for each series of the same general order of magnitude as those between brain-weight and age, though of course positive instead of negative, as they are in that case. Or it may be concluded that during adult life, at least, brain-weight is only a very little more closely related to general size of body, in so far as we may take stature as a measure of this, than to age. When we turn to the regression coefficients, however, it is seen that a unit of stature connotes a somewhat larger change of brain-weight than a unit of age. Thus, in the Swedish males, an increase of 10 cm. in stature connotes an increase in brain-weight of 28.59 gr., while an increase of 10 years in age connotes a decrease of 19.39 gr. in the brain-weight.

As in the correlation of brain-weight with age, the females have uniformly a higher degree of correlation between stature and brain-weight than the males. I am inclined to think that the same general sort of explanation may be given in this case as in that of the brain-weight and age correlations. The correlation between brain-weight and stature and the regression of brain-weight on stature are sensibly the same for the early adult period of life as for the total adult period. Without any question, I think, this correlation is to be regarded in its origin as a growth correlation, the relation between the two variables being

practically fixed at the end of the growth period. After that time the relation undergoes no marked change throughout the remainder of life, since both stature and brain-weight regress on age at not far from the same rate.

Finally, the combined effect of stature and age on the weight of the brain may be examined. This relationship can best be examined through the medium of multiple regression equations of the form:

$$x_1 = \beta_{12} x_2 + \beta_{13} x_3,$$

in which β_{12} and β_{13} are the partial regression coefficients of x_1 on its associated variables x_2 and x_3 , it being understood that x_1 , x_2 and x_3 here stand for deviations from the means of the respective variables. For our material these equations, when reduced to absolute magnitudes, take the following forms, the significance of the letters being the same as in the regression equations given before.

(19)	Swedish	♂	$W = 1091.021 + 2.288 S - 1.755 A,$	$\Sigma = 101.819$
(20)	"	♂	$W = 1080.715 + 2.362 s - 1.856 a,$	$\Sigma = 106.477$
(21)	"	♀	$W = 561.433 + 4.679 S - 1.078 A,$	$\Sigma = 93.066$
(22)	"	♀	$W = 533.407 + 4.854 s - 1.092 a,$	$\Sigma = 98.923$
(23)	Hessian	♂	$W = 942.154 + 2.989 S - 1.181 A,$	$\Sigma = 108.992$
(24)	"	♂	$W = 926.586 + 3.107 s - 1.318 a,$	$\Sigma = 108.889$
(25)	"	♀	$W = 1005.607 + 2.244 S - 2.173 A,$	$\Sigma = 94.261$
(26)	"	♀	$W = 974.382 + 2.345 s - 1.829 a,$	$\Sigma = 98.883$

These equations give the probable mean brain-weight of an array of adult individuals of either sex, having any given age (in years) and mean stature (in centimetres). They are, I believe, the first multiple regression equations relating brain-weight to stature, age and sex, to be published. They are of interest from several points of view. Examples of their practical use have been given earlier in the paper (pp. 25 and 48) in connection with the discussion of racial differences in mean brain-weight and later in connection with the sex differences. They afford a means whereby it is possible to make scientific comparisons of the mean brain-weight of different races, since by their use the probable brain-weight of a group of Swedes or Hessians having the same mean stature and age as the sample of the race with which comparison is to be made can be ascertained. We can in effect reduce both races to the same stature-age base and then examine the brain-weight differences. It would seem that these equations ought to prove very useful to anthropologists, who frequently wish to make comparisons of this kind. They are based on the two sets of brain-weighings which I believe to be on the whole the most reliable and trustworthy at present available. These equations also make it possible to determine the effect of indirect selection of stature and age on brain-weight.

As a practical example of this last use of these equations let us consider the following problem: By how much would it be necessary to modify the stature of a group of Swedish males, having a mean age of 45 years, in order that they might have the same mean brain-weight as a group of Bohemian males of the same mean

age? The mean brain-weight of the Bohemian males with a mean age of 45.699 is 1454.839 gr. From equation (19) we have then

$$1454.839 = 1091.021 + 2.288 S - (1.755 \times 45.699)$$

in which S is the mean stature of the selected group of Swedes. Solving we find

$$S = 194.06,$$

or, in other words, our group of Swedes would have a *mean* height of 6 ft. 4.4 in. ! Now as a matter of fact the Swedish males with a mean age of 45.02 years have a mean stature of 169.79 cm. In order then to get from the adult male Swedish population a group having the same mean brain-weight as the adult male Bohemian population, by a selection of stature alone, it would be necessary to raise the mean stature of the Swedes 24.3 cm. or roughly 9½ inches. Of course it is not for a moment to be supposed that evolution in brain-weight proceeds by the indirect selection of stature alone. Indeed when it is remembered that the mean stature of Bohemian males is only 169.4 cm. the example just cited shows how little the indirect selection of stature has to do with the matter. In the discussion of evolutionary problems, however, it is important to know just how much or how little effect each factor involved is capable of producing. It is in this direction of measuring the relative effect of different combinations of factors that regression equations such as those given above have great value.

It is apparent from equations (19) to (26) that stature and age in a measure compensate one another so far as their effect on brain-weight is concerned. The influence of stature is however in all cases greater. It is of some interest to know in the particular cases how great an increase in stature compensates a given increase in age and *vice versa*. In order to show this I have prepared the following table.

An increase of 10 cm. in stature is compensated in its effect on brain-weight by an increase in age in the

Swedish males of 13.0 years	} Total series only.
Swedish females of 43.4 "	
Hessian males of 25.3 "	
Hessian females of 10.3 "	

10. *Brain-weight and Body-weight.*

In only one of the four series of brain-weighings studied (the Bavarian) was body-weight tabulated in the returns. Recent workers on the subject have left this character out of their data on the general ground that it is of very doubtful significance or reliability in post-mortem returns from a general hospital population. Certainly it is true that it is influenced to a very marked degree by the

conditions preceding death. Yet as Donaldson* has pointed out if we could get this character free of disturbing ante-mortem effects it would furnish the best measure of the general "size" of the body. Since "size" of the body is one of the things to which brain-weight should first of all be related I decided to include in this study a consideration of the correlation of brain-weight with body-weight. I was fully aware of the weakness of the material and expected much worse results than those actually obtained. A glance at Table I will recall the facts as to the distribution of the frequency of body-weight. The means are of course lower than they would be for the living population of the same race and age. This is to be expected. The variation is large but there is very good accord between males and females in this respect. Turning now to the correlations I have arranged in Table XVI the values of r , η and Σ_M for the correlation between brain-weight and body-weight.

TABLE XVI.

Linearity of Regression. Brain-weight on Body-weight.

Race and Series	r		η		Σ_M	
	♂	♀	♂	♀	♂	♀
Bavarian (Total)	$\cdot1671 \pm \cdot0343$	$\cdot2260 \pm \cdot0412$	$\cdot1845$	$\cdot3189$	$\cdot0782 \sigma$	$\cdot2250 \sigma$

The result for the males is very satisfactory, indicating a quite reasonable approach to linearity of regression. The female series does not give so good a result, but it will be recalled that throughout the work this Bavarian female series has been found to be somewhat abnormal. The regression lines are shown in Diagrams XVIII and XIX.

DIAGRAM XVIII. Probable Brain-weight for given Body-weight.

* H. H. Donaldson: *The Growth of the Brain.*

Variation and Correlation in Brain-Weight

DIAGRAM XIX. Probable Brain-weight for given Body-weight.
Bavarian ♀ Total.

Through the great bulk of the observations the regression is evidently linear*. The male series comes very close to linearity.

The equations to the regression lines may now be given. In addition to the equation showing the regression of brain-weight on body-weight I have included multiple regression equations giving the probable brain-weight for given types of body-weight and stature together. The significance of the letters is as follows: W denotes the probable brain-weight of an array having a mean body-weight in kilograms W_B , or body-weight W_B and stature S . Σ is the standard deviation of the array.

(27)	Bavarian ♂	$W=1263.308+1.886 W_B,$	$\Sigma=118.439$
(28)	„ ♀	$W=1121.621+2.265 W_B,$	$\Sigma=103.495$
(29)	„ ♂	$W=917.748+2.234 S+1.355 W_B,$	$\Sigma=117.711$
(30)	„ ♀	$W=741.078+2.646 S+1.593 W_B,$	$\Sigma=102.432$

The correlation of brain-weight with body-weight is of about the same degree as the correlation of the former with the stature, but the regression approaches more closely to linearity in the case of body-weight. As in the other cases the female shows the higher correlation.

The absolute increase of brain-weight with every increase of 10 kilos. in body-weight is for the males 18.86 gr. and for the females 22.65 gr. Equations (29) and (30) show that in each case stature contributes absolutely more to an increase in brain-weight than does body-weight. The exact proportions are as follows: in order to bring about a change in brain-weight equal to that produced by an increase of stature of 10 cm. the body-weight would have to be increased 16.5 kilos. in the males, and 16.6 kilos. in the females. The greater dependence of the brain-weight on bodily characters in the female as compared with the male is very well shown in equations (29) and (30).

* Cf. pp. 61, 62.

11. *Brain-weight and Skull Characters.*

As was to be expected the correlation of brain-weight with the skull length and breadth gives the highest values for the coefficients of any of the correlations dealt with. In fact one would predict on general grounds, I think, a somewhat closer degree of correlation between these characters than is actually found in the Bohemian statistics. It is likely, however, that the values here obtained (Table XVII) are lower than they should be on account of the methods used in measuring skull length and breadth. As has been fully described above (p. 18) these measurements were taken on the horizontal cut surfaces after the dome of the skull had been removed by sawing around it. This is clearly not a very precise way in which to get skull measurements. In order to show so far as may be what has been the effect of this procedure I have prepared the following tables comparing the various constants of the Bohemian skull length and breadth series with other well-known cranial series. Taking first the means we have:

Race	Skull Length		Skull Breadth	
	♂	♀	♂	♀
Bohemians	176·547	170·142	149·841	144·953
Whitechapel English*...	189·06	180·36	140·67	134·68
Altbayerisch†	180·58	173·45	150·47	143·98
Württemberg†	179·48	172·74	147·88	142·90

The means give reasonably accordant values considering that the Bohemians are a markedly brachycephalic race. Turning next to the coefficients of variation we have:

Race	Skull Length		Skull Breadth	
	♂	♀	♂	♀
Bohemians	4·173	3·233	4·441	3·815
Whitechapel English† ...	3·31	3·45	3·75	3·54
Bavarian §	3·37	3·57	3·89	3·39
French 	3·97	3·65	4·21	3·67
Naqada¶	3·17	3·14	3·29	3·45
Aino §	3·20	3·08	2·76	2·68

* Macdonell, *Biometrika*, Vol. III. pp. 208, 209.

† Alice Lee, *Phil. Trans.* Vol. 196, A, pp. 225—264.

‡ Macdonell, *loc. cit.* p. 220.

§ Lee, *loc. cit.*

|| Unpublished reduction of Measurements in Broca's MS. by C. D. Fawcett.

¶ Miss Fawcett, *Biometrika*, Vol. I. pp. 438 and 456.

The Bohemian females are fairly accordant in variability with the other series in both length and breadth, but the males are apparently somewhat more variable. This greater variability in the Bohemian male series is due I believe not to less homogeneous material but to the manner in which the measurements are made. The coefficients of correlation between length and breadth may next be considered.

Race	♂	♀
Bohemians	·4006	·1954
Whitechapel English*	·240	·350
French†	·089	—·042
German‡	·286	·488
English Criminals§	·402	—
English Middle Classes§...	·345	—
Aino‡	·432	·376
Naqada†	·344	·143

The results here are somewhat chaotic, but clearly the difference in degree of correlation between Bohemian males and females is too great to be entirely normal. It is probable that the male coefficient is somewhat too high and the female too low. The agreement between the Bohemian male coefficient and Macdonell's value for measurements on the heads of living English criminals is striking. We should expect measurements made as the Bohemian were, to agree better with measurements on the living head than with those from the skull.

The practical result to which we come is that conclusions from the Bohemian data as to the correlation between brain-weight and skull length and breadth must be only tentative until they can be tested by other less objectionable material.

We may now examine in more detail the results as to the correlation of brain-weight with these skull characters. In Table XVII are given the values of r , η , and Σ_M .

TABLE XVII.

Linearity of Regression. Brain-weight and Skull Characters.

Race and Series	r		η		Σ_M	
	♂	♀	♂	♀	♂	♀
Bohemians, Skull Length	·5482 ± ·0273	·3604 ± ·0465	·5660	·4032	·1408 σ	·1808 σ
„ „ Breadth	·4655 ± ·0306	·5041 ± ·0399	·5498	·5368	·2926 σ	·1845 σ

The four regression diagrams concerned are Diagrams XX to XXIII.

* Macdonell, *loc. cit.* p. 233.

† C. D. Fawcett, *loc. cit.*

‡ Lee, *loc. cit.*

§ Macdonell, *Biometrika*, Vol. I. pp. 181 and 188, "Measurements on living head and not skull."

DIAGRAM XX. Probable Brain-weight for given Skull Length.

Bohemian ♂ Young. 20—59 years.

Variation and Correlation in Brain-Weight

DIAGRAM XXI. Probable Brain-weight for given Skull Breadth.
Bohemian ♂ Young. 20—59 years.

DIAGRAM XXII. Probable Brain-weight for given Skull Length.
Bohemian ♀ Young. 20—59 years.

DIAGRAM XXIII. Probable Brain-weight for given Skull Breadth.
Bohemian ♀ Young. 20—59 years.

Through the bulk of the observations the regression is very evidently linear. Diagram XXI shows that the considerable deviations of η from r and Σ_M from zero in the case of the male brain-weight and skull breadth regression are really due to the inclusion in the material of five individuals which are to be regarded as either erroneously measured or recorded, or else abnormal or extremely rare normal cases (cf. Table 31, Appendix).

The regression equations follow. In these equations W denotes the probable brain-weight in grams of an array of individuals having a mean skull length L and skull breadth B in millimetres.

(31)	Bohemian ♂	$W=8.589 L - 52.650,$	$\Sigma = 96.548$
(32)	„ ♂	$W=8.076 B + 253.596,$	$\Sigma = 102.170$
(33)	„ ♀	$W=6.215 L + 264.265,$	$\Sigma = 88.466$
(34)	„ ♀	$W=8.646 B + 68.434,$	$\Sigma = 81.908$
(35)	„ ♂	$W=6.751 L + 5.082 B - 489.649,$	$\Sigma = 99.745$
(36)	„ ♀	$W=4.696 L + 7.766 B - 602.994,$	$\Sigma = 77.893$

One rather curious point may be noted here in passing. As the figures stand a smaller probable error will be made in estimating the mean brain-weight of males from a knowledge of skull length alone (equation 31) than if both length and breadth of skull are used. This apparent paradox arises for the following reason*. The standard deviation of the array in the regression of x_1 on its associated variables x_2 and x_3 is given by

$$\Sigma = \sigma_1 \sqrt{1 - R_1^2},$$

where

$$R_1^2 = \frac{r_{12}^2 + r_{13}^2 - 2r_{12}r_{13}r_{23}}{1 - r_{23}^2}.$$

When the regression is of x_1 on x_2 alone the standard deviation of the array is

$$\Sigma = \sigma_1 \sqrt{1 - r_{12}^2}.$$

* Cf. Yule, *loc. cit.*

Now the condition under which we shall make a smaller standard error in estimating x_1 from the two variables x_2 and x_3 than in estimating it from x_2 only, is evidently that

$$(1 - R_1^2) < (1 - r_{12}^2)$$

or that

$$R_1^2 > r_{12}^2.$$

Now in the case noted above $R_1^2 < r_{12}^2$, the figures being $\cdot2534 < \cdot3005$.

Returning to the main line of the discussion, the results as to the correlation of brain-weight with skull characters are not altogether satisfactory, as they are apparently not entirely in accord with themselves. One of the points here on which information is most desired is whether brain-weight is more closely correlated with length or breadth of skull. According to our results brain-weight is more closely correlated with length of skull in the male and breadth of skull in the female. This seems a somewhat anomalous result as there is no apparent reason why one should not expect the sexes to show the same relation in the matter. However, Macdonell's (*loc. cit.*) figures for the correlation of skull capacity with length and breadth show a similar relation but in the opposite direction. He finds for the Whitechapel English skulls that the correlation between capacity and length is lower than the correlation between capacity and breadth in the males, and higher in the females. Other skull series do not, however, show this reversed relationship between the sexes. With the data at present available one cannot reach any general conclusion as to the relative closeness of correlation between brain-weight and skull length and breadth. It is very much to be hoped that future collectors of brain-weight statistics will include in their returns such head measurements as length, breadth, height and circumference taken before the cranial cavity is opened, and by standard anthropometrical methods.

A comparison of the values of the coefficients of correlation between brain-weight and skull length and breadth and between skull capacity and these characters is of interest. I have adapted the following table from Macdonell's* Table XIII.

Race	Brain-weight and Skull Length		Brain-weight and Skull Breadth	
	♂	♀	♂	♀
Bohemians ...	$\cdot5482 \pm \cdot0273$	$\cdot3604 \pm \cdot0465$	$\cdot4655 \pm \cdot0306$	$\cdot5041 \pm \cdot0399$
	Skull Capacity and Length		Skull Capacity and Breadth	
English* ...	$\cdot597 \pm \cdot051$	$\cdot691 \pm \cdot040$	$\cdot631 \pm \cdot048$	$\cdot646 \pm \cdot044$
Naqada † ...	$\cdot501 \pm \cdot054$	$\cdot599 \pm \cdot039$	$\cdot434 \pm \cdot058$	$\cdot532 \pm \cdot044$
German ‡ ...	$\cdot515 \pm \cdot050$	$\cdot687 \pm \cdot037$	$\cdot672 \pm \cdot037$	$\cdot706 \pm \cdot034$
Aino ‡ ...	$\cdot893 \pm \cdot016$	$\cdot663 \pm \cdot053$	$\cdot561 \pm \cdot053$	$\cdot502 \pm \cdot070$

* Macdonell, *loc. cit.* p. 235.

† Fawcett, *loc. cit.*

‡ Lee, *loc. cit.*

The brain-weight correlations with two exceptions are smaller than the corresponding skull capacity correlations. A portion at least of this difference is probably to be accounted for on the ground that brain-weight fluctuates as a result of causes which do not at all affect skull capacity. Possibly the whole of the difference is to be accounted for in this way, but until there is available a more reliable collection of material on the brain-weight side the question cannot be definitely settled. Until such material is available we shall be justified, I think, in assuming that the values of the coefficients for the correlation between brain-weight and skull characters given by the male series probably represent more nearly the normal relation than do those of the female series.

Making all due allowance for the shortcomings of the material the following points are clearly brought out: (a) Brain-weight is positively correlated with both skull length and skull breadth. (b) The correlations here are higher than any of the other correlations of brain-weight with bodily characters. (c) The regression of brain-weight on these skull characters is approximately linear. (d) Indirect selection of skull characters is capable of modifying brain-weight to a considerable extent.

The use of equations (31) to (36) in selection problems has been illustrated above (p. 49). One other example may be given because it bears very directly on a question of perennial interest in certain quarters. The problem to which I have reference may be stated for our present purpose in this form: Does dolichocephaly imply a greater brain-weight than brachycephaly or *vice versa**? Mere inspection of equations (35) and (36) shows that neither dolichocephaly nor brachycephaly will have a great advantage over the other in respect to brain-weight, but the matter can be made somewhat more *anschaulich* by taking a particular example. Consequently I have chosen the following figures. In Macdonell's Tables I and II (*loc. cit.*) are given the values for cephalic index, skull-length and skull-breadth for a dolichocephalic race (the Whitechapel English series) on the one hand and a brachycephalic race (the Altbayerisch) on the other. Those values are as follows:

	♂		♀
English ...	Cephalic index = 74.34	English ...	Cephalic index = 74.73
Altbayerisch ...	" " = 83.20	Altbayerisch ...	" " = 83.10
English ...	Length = 189.06	English ...	Length = 180.36
" ...	Breadth = 140.67	" ...	Breadth = 134.68
Altbayerisch ...	Length = 180.58	Altbayerisch ...	Length = 173.45
" ...	Breadth = 150.47	" ...	Breadth = 143.98

* Evidently the real essence of the question, so far as it has what might be called "humanistic" interest, rests on the assumption of a reasonably high positive correlation between brain-weight and intellectual ability. "Brains" not brain-weights are the things! Up to this point I have carefully avoided any discussion of the validity of such an assumption as that mentioned, deeming it entirely irrelevant to the main purpose of the paper. The point is discussed in the concluding section.

Now using equations (35) and (36) for males and females respectively we have for the probable mean brain-weights of arrays having the types of length and breadth of the English and Altbayerisch series respectively, the following values:

♂	♀
English B.W. =1501·580 Altbayerisch B.W.=1494·135	English B.W. =1289·901 Altbayerisch B.W.=1329·676

In the males the dolichocephalic and brachycephalic arrays have practically equal brain-weights, while in the females the brachycephalic array gives a brain-weight about 40 grs. higher than the dolichocephalic. But, as has been pointed out above, the male equations probably come much nearer representing the normal relations than do the female. On the whole, then, there seems to be little or no evidence that either dolichocephaly or brachycephaly is associated with large brain-weight.

It should perhaps be noted that no significance is to be attached to the absolute values of the brain-weights calculated from the English and Altbayerisch skull types, as indicating the probable brain-weight of those races. The differences only are of significance. The measurements of these skulls were taken only for the sake of convenience; hypothetical dolichocephalic and brachycephalic skull means would have served the purpose as well. The brain-weights obtained are of course the probable mean brain-weight of arrays of *Bohemians* having the specified skull characters. Intra-racial regression equations can of course only be used for inter-racial prediction when the regression of all characters on one another is the same in both races, which is a condition never likely to be exactly fulfilled in practice. Of the races and characters discussed in this paper the Hessians and Swedes in brain-weight, stature, and age come nearest to fulfilling this condition.

12. *The Weight of the Cerebrum.*

Up to this point the discussion has had to do entirely with the variation and correlation of the whole brain or encephalon. In the manuscript material placed at my disposal by Prof. Donaldson (*vide supra*, p. 15) data were given from which it was possible to determine the variation in the weight of the cerebral hemispheres, and the correlation of this character with stature and age for English males. The results obtained from this material may now be examined. It should be stated that the records of weight were in ounces, and of stature in inches in the original material. The units of grouping and the distribution of the frequencies may be seen in Tables 45 and 46 of the Appendix. After the constants had been calculated in ounces and inches they were transferred to the metric system in order to facilitate comparison with the other parts of the paper. The values of the constants are exhibited in Table XVIII.

TABLE XVIII.

Variation in the Weight of the Cerebrum. English Males.

Boyd-Marshall Data.

Character	Mean			S. D.	C. of V.
	No.		Table		
Weight of cerebrum	308	1184.940 ± 4.859 gr.	45	126.438 ± 3.436 gr.	10.670 ± .293
Stature	308	171.602 ± .268 cm.	45	6.976 ± .190 cm.	4.065 ± .111
Age	308	49.481 ± .645 yr.	46	16.770 ± .456 yr.	—

For the correlation of weight of cerebrum with age I find from Table 46

$$r = -.1412 \pm .0377,$$

and for the correlation of the weight of cerebrum with stature from Table 45

$$r = .1202 \pm .0379.$$

These values bring out the following points. The cerebral hemispheres are markedly more variable in weight as judged by the coefficient of variation than is the entire encephalon. This greater variation may denote a really greater variability of this part of the brain, or it may be due to the variable element which enters as a result of the separating of these organs from the rest of the brain. It seems to me likely that it is in part at least real, for the following reasons: first, the cerebral hemispheres have attained relatively enormous development late in their phylogenetic history; and again from the functional standpoint the cerebrum is the most variable part of the brain.

The correlations of the weight of the cerebrum with age and stature are both somewhat lower than the corresponding values for the other series of males falling within the ages 20 to 80. The differences can hardly be considered as significant however in view of the probable errors.

For the coefficient of regression of brain-weight on age I find $b_1 = -1.065$, and on stature $b_1 = 2.178$. By comparing these with the regression coefficients for the entire encephalon on the same characters in the series previously discussed it becomes evident at once to what a great extent changes in the total brain-weight are due to changes in the weight of the cerebrum. Unfortunately it is not possible to get relative figures here on account of lack of knowledge of the regression of the total brain-weight on stature and age for the English series. Of course the weight of the cerebrum forms a large part (ca. 87 per cent for the English series) of the total brain-weight. The problem here is to determine whether the changes in the weight of the cerebrum cause less or more than their proportional part (say 87 per cent.) of the changes in total brain-weight due to stature and age changes. I have tried a number of approximate methods

of getting at this question with the data available, but none of them led to any result sufficiently well grounded to warrant taking space for its publication. Putting all the results so obtained together they seemed to indicate the following conclusion, which is of course subject to modification when further material is available: viz., that changes in stature affect all parts of the brain equally (i.e., in the proportion of their absolute masses) while changes in age have a relatively greater effect on the cerebral hemispheres than on the remainder of the brain (cerebellum, pons, and medulla).

The final conclusions regarding variation and correlation in the weight of the cerebrum may be summed up as follows: the cerebrum is somewhat more variable in weight than is the entire encephalon, and this character is slightly less closely correlated with age and stature. The values of the variation and correlation constants are, however, as is to be expected, of the same general order of magnitude as those for the total brain-weight.

13. *Concluding Remarks.*

In concluding this paper I wish to call attention to what seem to me to be some of the broader aspects of the work. There are at least two general results of the work which alone justify its being done, I think. The first and most important is that the paper contributes reduced material to the existing collection of biometric data on man. In the nature of the case such a collection grows slowly, but every increase in it means a definite, although it may be small, step in advance in our knowledge regarding the fundamental problems of anthropology. I regard as the second most important result the fact that it may now fairly be said that the essential trustworthiness of the most important of the existing collections of brain-weight statistics has been demonstrated, and that consequently reasoning by statistical methods on the problems involved is not of necessity lacking in validity. The agreement in the statistical constants from four series of data so divergent in their origin as those treated in this paper cannot reasonably be held to be fortuitous. It can mean, I think, but one thing, namely, that the same kind of general lawfulness underlies the variation and correlation of brain-weight and the variation and correlation in other characters of the organism. With this conclusion presumably no student of brain-weight would disagree, but some of the most eminent students have disagreed with the converse proposition that it is possible to gain a knowledge of the nature of this lawfulness by statistical methods applied to large masses of material when brain-weight is the thing concerned. This sceptical attitude owes its origin, I think, to the nature of the statistical methods which have hitherto been applied to the problem. Brain-weight statisticians have erred in two directions in the handling of their material. On the one hand, following the much-to-be-condemned practice in other fields of anthropology, entirely heterogeneous material has been grouped together to attain large total numbers. The culminating example here is, perhaps, Topinard's series of the brain-weights of 13,000 Europeans. Secondly, certain brain-weight workers

have attempted to apply to the individual results gained by somewhat doubtful statistical analysis of mass data, and *vice versa*, what is much worse, have argued that the relations found to hold in a single individual might be considered to hold for the mass. As an example here might be cited Marshall's* attempt to correct the brain-weights of De Morgan, Thackeray, and others for stature and age. The results detailed in this paper will indicate to the biometrician at least how dangerous both of these methods of procedure are with such material as brain-weight statistics. Of course both disregard fundamental canons of general statistical theory, but the chance of grave error becomes very much greater when the character under consideration shows on the one hand definite and clearly marked types in different races, and on the other hand low correlations†. With the application of adequate statistical methods it is possible to reach definite and significant results regarding the weight of the brain. When we have biometric constants for a considerable number of long series of brain-weight statistics from different races we shall be able to advance our knowledge greatly with reference to the general problems of the evolution of man's brain.

While the discussion of such problems can at the present time admittedly lead to only tentative results, still I think it will be worth while to examine for a moment the bearing of our results on a single evolution problem. Progressive evolution through natural selection may be brought about in any character either by the direct selection of that particular character or by the indirect selection of other characters correlated with it. As we proceed in the analysis of the problem the proportional effect of each of these two sets of factors must be quantitatively determined. A first approximation to such a determination has been here made

* *Loc. cit.*, *supra*, p. 18.

† In this connection Weigner's recent paper "Ein Beitrag zur Bedeutung des Gehirngewichts beim Menschen," *Anatomische Hefte*, Bd. 23, pp. 69—109 is decidedly open to criticism. But when one, after very briefly analyzing the weighings of 69 male and 66 female brains (*sic*) from individuals ranging in age from 1½ to 82 years, by the most superficial of statistical methods, feels justified in drawing the following sweeping conclusions *inter alia*, what can biometry offer that will be in any way effective? Weigner's three principal conclusions as to fact are (*loc. cit.* p. 108):

1. "Das Gehirngewicht steht in keinem direkten Zusammenhang mit dem Alter, und wenn auch die angegebenen Zahlen sich zu Gunsten dieses Zusammenhanges verwerthen einen, verlieren dieselben an der Bedeutung, da durch dieselben nicht der Beweis geführt werden kann, wie sich Gehirngewicht bei einem und demselben Individuum in verschiedenen Altersperioden verhält;

2. zwischen dem Gehirngewichte und der Körperlänge lässt sich keine bestimmte Proportion feststellen;

3. die Durchschnittszahl hat bloss einen relativen Wert, und zwar deshalb, weil die das Gehirngewicht repräsentierenden Zahlen durch die Wägung eines zufällig uns gerade zur Verfügung stehenden Materials gewonnen sind und das aus demselben bestimmte arithmetische Mittel keine konstante Grösse, sondern eine frei bewegliche Reihe von Zahlen uns darstellt."

It should be said that the material on which these conclusions are based is apparently within the limits of its probable errors entirely normal, and shows an approximately linear regression of brain-weight on age during adult life. This being the case the very positive conclusions seem to take on the character of extreme dogmatism. If 1. were true, by the same token no life insurance company could fix upon a premium rate for the insurance of lives of individuals, aged 21 say, which would enable it to carry on its business justly and fairly, because no life insurance company knows when any one individual aged 21 will die. Yet life insurance companies seem to be struggling on!

for brain-weight and "size of body." It has been shown (p. 66) that of a given change in mean brain-weight between 25 and 30 per cent. can be brought about by a selection of "size of body," measuring this both by stature and weight of body. As it is fair to assume that natural selection has acted on "size of body" we thus reach some idea of how much of an effect such selection has had on the weight of the brain.

A vital point at issue is as to what are the underlying causes of brain-weight differences. We have seen that there are definite racial types in brain-weight apart from differences in the other bodily characters which could be studied in this connection. To take a concrete example, we find that groups of male and female Bohemians having the same mean length and breadth of skull have probable mean brain-weights differing by about 69 grams, the female mean being lower than the male, of course. To what is this difference to be ascribed? Evidently there are a considerable number of possible factors which may enter into the matter. In the first place these males and females would still differ in stature by a certain amount so that a part of the remaining brain-weight difference would be accounted for in this way, but probably less than 25 per cent. Selecting too the same skull size would undoubtedly reduce the gross sexual difference in stature to some extent. The mean age of the arrays is essentially the same, so that nothing is gained from this source. To account for the still remaining difference there are at least the following possible factors:

1. The specific gravity of the female brain may be lower.
2. A unit increase in skull length and breadth may be associated with a greater change in skull height in the male than in the female.
3. The walls of the female skull may be thicker than in the male.
4. The female brain may fill the skull cavity less closely than does the male. (The opposite has been stated to be the case. Cf. Donaldson, *loc. cit.* p. 118.)
5. The ventricles of the brain may be proportionately larger in the female than in the male brain.

With the material at present available it is impossible to determine which of these possible factors really play the important rôle. It is my purpose merely to call attention to the kind of problem that confronts one at this point in the analysis of brain-weight constants. It at least will serve to show some of the directions in which more definite information is desired.

Donaldson* has well said: "The search for correlation between the size and form of the brain and the degree of the intelligence has interested all who have worked on this organ, and although it might be designated as the psychologist's standpoint, it has, from the very first, been in some measure before the minds of all." This point has so far been avoided in this paper for the reason that it seemed to me desirable to settle the question of the purely physical variations and

* *Loc. cit.* p. 85.

correlations before making any attempt on the much more difficult matter of brain-weight and intelligence correlation. I have, however, one point to add to the discussion of this already much debated subject. It follows rather simply from the theory of multiple correlation and regression that if the correlation coefficients r_{12} and r_{13} measuring the correlation between characters x_1 and x_2 , and x_1 and x_3 , are known, then it is possible to determine the limits between which the value of the coefficient of correlation r_{23} between x_2 and x_3 must lie. Without going into the details of the theory involved, which is given in convenient form by Yule*, it may be said that since

$$(r_{23} - r_{12}r_{13})^2 \text{ is not } > 1 + r_{12}^2 r_{13}^2 - r_{12}^2 - r_{13}^2,$$

r_{23} must lie between the limits

$$r_{12}r_{13} \pm (\sqrt{1 + r_{12}^2 r_{13}^2 - r_{12}^2 - r_{13}^2}).$$

Now, very fortunately, Pearson and his co-workers† at University College have determined for Cambridge undergraduates the correlation between "intelligence" as denoted by place in degree examinations and certain physical characters whose correlation with brain-weight we also know. Evidently then we have the material for getting at an approximation of the limits of the correlation between brain-weight and intelligence except that the two correlations from which the limits of the third are to be determined are not from the same material. This of course introduces an element of error, but as the coefficients of correlation of brain-weight with other characters seem to be fairly constant from race to race, a very serious error will probably not be made in assuming that the values of these correlations would not differ greatly in the English from what they are for continental races or from one another in two different groups of English. Leaving for the moment this question of possible error, let us examine the figures, first taking this problem: Assuming that Cambridge undergraduates have the weight of the cerebrum correlated with stature to roughly the same degree as is shown in Boyd's English data, what will be the limits of the correlation between weight of cerebrum and intelligence? The necessary data are as follows:

$r_{12} = -.0056$ correlation coefficient between stature and intelligence.

$r_{13} = .12$ " " " " " " weight of cerebrum.

The limits of r_{23} , or of the coefficient of correlation between brain-weight and intelligence, are roughly $+.98$ and $-.99$. Now r_{12} is really insignificant, the conclusion the authors draw being that (*loc. cit.* p. 107), "stature is not correlated with place in degree examinations." Putting $r_{12} = 0$ the limits of r_{23} are $\pm \sqrt{1 - r_{13}^2}$. Or the practical conclusion we reach is that, so far as the known correlations of weight of cerebrum and intelligence respectively with stature give evidence, the correlation between weight of cerebrum and intelligence may have any value

* *Loc. cit.*

† Lee, A. Lewenz, M.A., and Pearson, K.: "On the Correlation of the Mental and Physical Characters in Man, Part II." *Roy. Soc. Proc.* Vol. LXXI. pp. 106—114, 1902.

between 0 and ± 1 . There is no evidence from this source as to whether the correlation is positive or negative. Suppose we take still another case, stating the problem this time in this way: Assuming that the Cambridge undergraduates have brain-weight correlated with skull length to roughly the same degree as is shown by Bohemian males, what will be the limits of the correlation between brain-weight and intelligence? The necessary coefficients are:

$r_{12} = .0861$ correlation coefficient between skull length and intelligence.

$r_{13} = .5482$ „ „ „ „ „ and brain-weight.

The limits of r_{23} or the correlation between brain-weight and intelligence, are $+.7$ and $-.6$, or practically we reach much the same result as before. Now the Bohemian coefficient, as we have seen, probably is in error in the direction of being too small, or the probability is that the limits of r_{23} are still wider than the figures indicate. As to the reliability of these limits this may be said: in order to fix correctly the sign of the correlation between brain-weight and intelligence, both the coefficients between intelligence and physical characters and brain-weight and the same physical characters would have to be greater than $\sqrt{.5}$ or $.707$. Now I think it is reasonably evident from what we already know, that for civilized man at least there is no likelihood whatever of ever finding values as high as $.707$ for the coefficients concerned. Or in other words the degree of the correlation between brain-weight and intelligence is indeterminate, with the probability that it is sensibly equal to zero. That is, brain-weight and intelligence in the sense of mental capacity are probably not sensibly correlated. All the inferential evidence when subjected to careful scrutiny leads to the same conclusion, I think.

In closing I may perhaps be permitted to point out what seem to me to be the most promising lines for future investigation of the problems regarding the weight of the brain. In the first instance it seems to me highly desirable to transfer the problem for a time at least from man, where in the nature of the case all the fundamental records must be vitiated from the fact that we cannot weigh the brains of any considerable number of normal men instantly killed. As a consequence of this impairment of the data resulting from complex ante-mortem conditions the *absolute* values of certain of the biometric constants concerned cannot in the case of man be proven to be sensibly identical with what we should consider necessarily normal values. To be sure, such a sensible identity cannot, on the other hand, be disproven, but a state in which one can neither prove nor disprove is scientifically not altogether satisfactory. By working with animals it is possible to weigh any number of brains of instantly killed normal individuals. From records so obtained the values of the important biometric constants like the coefficients of correlation can be satisfactorily determined. In the hands of Prof. Donaldson this line of work is yielding results of the greatest significance and value. For continuing the work on the human side the primary need is for more and larger collections of brain-weights in which close attention is paid to the racial homogeneity of the material and to the recording of other subsidiary facts

as well as brain-weight. In comparison with the present series of brain-weighings a series which should record the following facts would be almost ideal.

1. Brain-weight, by the standard method.
2. Race. In this the more essential detail given the better.
3. Country of residence during adult life.
4. Occupation (as an index of social status).
5. Immediate cause of death.
6. Chronic diseases of adult life.
7. Stature.
8. Body-weight.
9. Head length.
10. Head breadth.
11. Head height.
12. Maximum horizontal circumference of head.
13. Age.
14. Sex.

} Measurements all made before skull is opened, and with hair removed at points of contact.

Such a list at first sight appears formidable from the practical standpoint, but evidently the things which would give the greatest difficulty are 2 to 6 inclusive. The head measurements could be made with little trouble, and a relatively small expenditure of time. This list is presented with the hope that any future workers who may be about to undertake the great labour involved in obtaining a large mass of human brain-weight statistics will at least consider the points raised. The few additional facts would take but little more time in the collection, and they would greatly enhance the value of the completed series. I would especially call attention to the need for larger series of brain-weight statistics than those we now have. In order to do really "close" statistical work on the subject it is desirable that we have larger arrays of individuals of given age and stature types in order that the regressions may be smoothed and the brain-weights in more absolutely homogeneous material may be investigated.

Finally it should be said that the present paper is, from the biometrical standpoint, only a "first" study of the problems of brain-weight correlation. Much yet remains to be done, and as will have been apparent to the reader could be done with the present material. One thing especially which might be done is to separate the material into a third "old" group, comprising the individuals falling in age between 50 and 80, and treat this group separately. I very much doubt, however, in view of the apparent substantial linearity of the regression of brain-weight on age through the whole of adult life, and considering the statistically small number of individuals which in each case would have been available, whether the value of the results so obtained would have been in any way commensurate with the labour involved. Even a biometrician must stop somewhere. When we have much larger collections of brain-weight statistics to work with an old age division of the material will be at least experimentally justified.

14. *Summary.*

Some of the more important, general conclusions of a study of five series of brain-weighings, representing Swedish, Hessian, Bavarian, Bohemian, and English sub-races of man and including altogether the weights of 2100 adult male and 1034 adult female brains, may be summarised as follows:

1. There are definite racial types in brain-weight. The differences between racial groups in this character are only in part to be accounted for by differences in other characters of the body.
2. The series studied exhibit a very fair degree of homogeneity.
3. In respect to variability the characters, brain-weight and skull capacity are sensibly equal. The coefficients of variation for brain-weight are intermediate in value between those which have been determined for skeletal characters in man on the one hand, and those for the weights of the viscera and for various physiological characters on the other hand.
4. Having regard to the size of the present series we conclude that variation in weight of the brain may for practical purposes be considered to follow the "normal" law of the distribution of errors. If the mean and the mode do not exactly coincide the mean will be slightly greater than the mode in brain-weight frequency distributions.
5. The correlation of brain-weight with age, stature and body-weight, is in all cases low.
6. The correlation of brain-weight with skull length and skull breadth is, in comparison with the other characters studied, fairly high, and is for both skull length and breadth positive.
7. The sexual differences in mean brain-weight are practically constant in all the races studied, whether considered absolutely or relatively.
8. Only a part of the sexual difference is to be accounted for by differences between the sexes in other bodily characters.
9. The sexes are equally variable in respect to brain-weight.
10. The weight of the brain tends to be more highly correlated with other characters in the female than in the male.
11. The correlation of brain-weight with age is negative. The regression of brain-weight on age is, so far as can be determined from our present series, linear throughout the period of life comprised between the ages 20 to 80. In other words, there is a steady decline in the weight of the brain with advancing age, beginning at about the twentieth year and continuing throughout adult life.

12. The correlation of brain-weight with stature and with body-weight is positive and in each case the regression is linear.

13. The weight of the cerebrum follows the same laws of variation and correlation as does the weight of the entire brain, but exhibits a somewhat greater relative variability.

14. The results as to variation and correlation in brain-weight are closely accordant for all the races studied.

15. The indirect selection of bodily characters can modify the mean weight of the brain to a considerable extent. The amount of this effect has been measured in certain cases.

16. There is no evidence that brain-weight is sensibly correlated with intellectual ability. The limits of this correlation have been shown to be not closer than 0 and $\pm .6$.

17. So far as can be determined from present material dolichocephaly has associated with it no advantage in mean brain-weight over brachycephaly and *vice versa*.

18. There is great need for further large and homogeneous collections of brain-weight statistics. When these are available for a considerable number of races it will be possible to pass from intra-racial to inter-racial problems.

APPENDIX OF MEASUREMENTS.

Correlation Tables.

The fundamental correlation tables on which the results of this paper are based have been placed together here at the end for convenience in reference. The tables are numbered consecutively in Arabic numerals, and each bears its own explanation. A word may be said as to the plan of arrangement. The racial order is

Swedes	Tables	1	to	12	inclusive.
Hessians	"	13	"	24	"
Bohemians	"	25	"	34	"
Bavarians	"	35	"	44	"
English	"	45	and	46	"

Under each race the order of arrangement is in each case for the tables involving brain-weight as one of the variables to precede the subsidiary tables involving only the related characters. The tables of males precede those for females, and the "total" series precede the "young."

TABLE 1.

Swedes. Brain-weight and Stature. "Total" Series. Males.

Stature (centimetres).

Brain-weight (grams).	Stature (centimetres).																Totals
	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188	189—191	
1100—1149	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
1150—1199	—	—	—	—	—	2	3	1	—	2	2	—	—	—	—	—	10
1200—1249	—	—	1	—	—	4	2	5	5	1	1	1	—	1	—	—	21
1250—1299	—	1	—	—	4	3	5	8	8	6	3	3	—	3	—	—	44
1300—1349	1	—	—	—	2	4	4	7	11	9	7	6	2	—	—	—	53
1350—1399	1	1	—	—	1	7	17	21	11	13	6	5	3	—	—	—	86
1400—1449	—	—	1	1	—	2	9	10	13	13	8	11	2	2	—	—	72
1450—1499	—	—	1	1	1	4	6	8	13	8	9	5	1	2	—	1	60
1500—1549	—	—	—	—	—	1	1	2	4	5	7	4	4	—	—	—	28
1550—1599	—	—	—	—	1	3	—	6	1	4	2	6	2	—	—	—	25
1600—1649	—	—	—	—	—	—	—	3	4	4	—	1	—	—	—	—	12
1650—1699	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—	—	3
1700—1749	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	2	2	3	2	10	29	47	72	71	66	45	44	14	8	—	1	416

TABLE 2.

Swedes. Brain-weight and Stature. "Total" Series. Females.

Stature (centimetres).

Brain-weight (grams).		132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	Totals
900— 949	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
950— 999	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1000—1049	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
1050—1099	—	—	—	—	1	—	3	—	1	1	1	1	1	—	—	—	9
1100—1149	1	—	—	1	—	2	3	2	6	4	4	2	3	1	—	—	28
1150—1199	—	—	—	—	1	2	3	3	8	7	1	3	3	2	—	—	30
1200—1249	—	—	—	1	—	2	3	6	9	11	3	12	4	2	—	—	53
1250—1299	—	—	—	—	—	—	3	1	8	5	9	3	7	2	—	2	40
1300—1349	—	—	—	—	—	—	—	—	4	8	6	6	5	1	—	—	30
1350—1399	—	—	—	—	—	1	—	1	5	3	3	5	2	2	1	—	23
1400—1449	—	—	—	—	—	—	—	—	1	1	1	3	3	1	—	—	10
1450—1499	—	—	—	—	—	—	—	—	1	—	2	2	—	—	—	1	6
1500—1549	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
1550—1599	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Totals		1	—	2	1	6	14	14	44	40	30	38	28	11	1	3	233

TABLE 3.

Swedes. Brain-weight and Stature. "Young" Series. Males.

20—50 years.

Stature (centimetres).

Brain-weight (grams).	Stature (centimetres).																Totals
	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188	189—191	
1100—1149	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1
1150—1199	—	—	—	—	—	1	2	—	—	1	—	—	—	—	—	—	4
1200—1249	—	—	1	—	—	2	1	4	2	1	1	—	—	1	—	—	13
1250—1299	—	—	—	—	1	1	2	5	3	2	—	2	—	—	—	—	18
1300—1349	1	—	—	—	—	4	4	5	7	3	6	5	—	2	—	—	35
1350—1399	1	—	—	—	—	4	11	12	6	7	6	4	2	—	—	—	53
1400—1449	—	—	—	—	—	1	3	6	8	10	5	8	1	1	—	—	43
1450—1499	—	—	1	1	—	2	5	7	10	3	5	4	—	1	—	1	40
1500—1549	—	—	—	—	1	—	1	1	3	3	7	2	3	—	—	—	21
1550—1599	—	—	—	—	1	3	—	3	1	3	2	4	2	—	—	—	19
1600—1649	—	—	—	—	—	—	—	2	4	4	—	1	—	—	—	—	11
1650—1699	—	—	—	—	—	—	—	1	1	—	—	1	—	—	—	—	3
1700—1749	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	2	—	2	1	3	18	29	46	45	38	32	32	8	5	—	1	262

TABLE 4.

Swedes. Brain-weight and Stature. "Young" Series. Females.

20—50 years.

Stature (centimetres).

Brain-weight (grams).		138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	Totals
900—949	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
950—999	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1000—1049	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
1050—1099	—	1	—	—	1	—	—	—	—	—	—	—	—	—	2
1100—1149	1	—	—	1	1	—	2	2	2	1	2	—	—	—	12
1150—1199	—	—	—	1	—	2	3	5	—	1	2	2	—	—	16
1200—1249	—	—	—	2	2	1	2	5	3	6	1	2	—	—	24
1250—1299	—	—	—	—	2	—	5	2	5	3	5	2	—	2	26
1300—1349	—	—	—	—	—	—	2	3	4	4	2	1	—	—	16
1350—1399	—	—	—	1	—	1	3	2	1	3	1	1	1	—	14
1400—1449	—	—	—	—	—	—	1	—	1	3	2	1	—	—	8
1450—1499	—	—	—	—	—	—	1	—	2	2	—	—	—	1	6
1500—1549	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1550—1599	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
Totals		1	1	5	6	5	20	19	18	23	16	9	1	3	127

Variation and Correlation in Brain-Weight

TABLE 5.

Swedes. Brain-weight and Age. "Total" Series. Males.

Brain-weight (grams).

Age (years).	Brain-weight (grams).													Totals
	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	1700—1749	
20—24	—	—	—	1	6	5	2	7	2	3	1	—	—	27
25—29	—	—	—	1	4	10	8	4	2	2	3	2	1	37
30—34	—	1	2	—	5	13	8	6	5	3	4	1	—	48
35—39	1	2	1	6	4	8	9	9	4	4	1	—	—	49
40—44	—	1	9	6	10	9	10	5	5	4	2	—	—	61
45—49	—	—	1	4	6	8	6	9	3	3	—	—	—	40
50—54	—	—	1	7	4	15	7	9	4	2	1	—	—	50
55—59	—	1	3	4	9	6	7	6	1	2	—	—	—	39
60—64	—	4	1	7	2	4	8	3	1	2	—	—	—	32
65—69	—	1	2	4	3	2	3	2	1	—	—	—	—	18
70—74	—	—	—	2	—	4	—	—	—	—	—	—	—	6
75—79	—	—	1	2	—	2	4	—	—	—	—	—	—	9
Totals	1	10	21	44	53	86	72	60	28	25	12	3	1	416

TABLE 6.

Swedes. Brain-weight and Age. "Total" Series. Females.

Brain-weight (grams).

Age (years).	Brain-weight (grams).														Totals
	900—949	950—999	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	
20—24	—	—	—	—	—	1	2	6	5	—	2	2	—	—	18
25—29	—	—	—	—	1	7	3	—	1	3	1	—	—	1	17
30—34	1	—	—	1	3	—	2	8	—	3	—	2	—	—	20
35—39	—	—	—	—	2	4	5	4	5	2	2	2	—	—	26
40—44	—	—	1	—	4	3	7	5	3	5	2	—	—	—	30
45—49	—	—	—	1	2	1	5	3	2	1	1	—	—	—	16
50—54	—	—	—	2	4	1	6	1	2	3	2	—	—	—	21
55—59	—	—	—	2	4	5	6	1	6	4	—	—	—	—	28
60—64	—	—	—	—	1	5	8	5	4	2	—	—	—	—	25
65—69	—	—	—	1	1	1	3	4	2	—	—	—	—	—	12
70—74	—	—	—	1	4	2	4	2	—	—	—	—	1	—	14
75—80	—	—	—	1	2	—	2	1	—	—	—	—	—	—	6
Totals	1	—	1	9	28	30	53	40	30	23	10	6	1	1	233

TABLE 7.

Swedes. Brain-weight and Age. "Young" Series. Males.

Brain-weight (grams).

Age (years).	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	1700—1749	Totals
20—24	—	—	—	1	6	5	2	7	2	3	1	—	—	27
25—29	—	—	—	1	4	10	8	4	2	3	3	—	—	37
30—34	—	1	2	—	5	13	8	6	5	3	4	1	—	48
35—39	1	2	1	6	4	8	9	9	4	4	1	—	—	49
40—44	—	1	9	6	10	9	10	5	5	4	2	—	—	61
45—49	—	—	1	4	6	8	6	9	3	3	—	—	—	40
Totals	1	4	13	18	35	53	43	40	21	19	11	3	1	262

TABLE 8.

Swedes. Brain-weight and Age. "Young" Series. Females.

Brain-weight (grams).

Age (years).	900—999	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	Totals
20—24	—	—	—	—	—	1	2	6	5	—	2	2	—	—	18
25—29	—	—	—	—	1	7	3	—	1	3	1	—	—	—	17
30—34	1	—	—	1	3	—	2	8	—	3	—	—	—	—	20
35—39	—	—	—	—	2	4	5	4	5	2	2	2	—	—	26
40—44	—	—	1	—	4	3	7	5	3	5	2	—	—	—	30
45—49	—	—	—	1	2	1	5	3	2	1	1	—	—	—	16
Totals	1	—	1	2	12	16	24	26	16	14	8	6	—	1	127

TABLE 9.

Swedes. Stature and Age. "Total" Series. Males.

Stature (centimetres).

Age (years).	Stature (centimetres)															Totals	
	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188		189—191
20—24	—	—	—	—	—	—	3	1	5	4	7	3	2	1	—	1	27
25—29	—	—	—	—	—	1	1	7	4	6	6	10	1	1	—	—	37
30—34	—	—	1	—	1	2	5	9	12	6	6	4	—	2	—	—	48
35—39	1	—	—	1	—	5	4	12	9	6	3	6	2	—	—	—	49
40—44	—	—	1	—	1	6	8	12	9	11	5	5	3	—	—	—	61
45—49	1	—	—	—	1	4	8	5	6	5	5	4	—	1	—	—	40
50—54	—	2	—	—	1	2	9	8	10	6	3	4	3	2	—	—	50
55—59	—	—	—	—	2	2	3	7	6	9	5	2	2	1	—	—	39
60—64	—	—	1	—	3	3	4	7	3	8	1	1	1	—	—	—	32
65—69	—	—	—	—	1	2	1	1	5	3	2	3	—	—	—	—	18
70—74	—	—	—	—	—	1	—	1	1	1	1	1	—	—	—	—	6
75—79	—	—	—	1	—	1	1	2	1	1	1	1	—	—	—	—	9
Totals	2	2	3	2	10	29	47	72	71	66	45	44	14	8	—	1	416

TABLE 10.

Swedes. Stature and Age. "Total" Series. Females.

Stature (centimetres).

Age (years).	Stature (centimetres)															Totals
	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	
20—24	—	—	—	—	—	—	—	1	3	4	6	2	1	—	1	18
25—29	—	—	1	—	—	—	—	3	4	1	2	2	4	—	—	17
30—34	—	—	—	—	—	3	2	3	1	2	—	7	—	1	1	20
35—39	—	—	—	—	—	2	2	4	3	6	6	2	1	—	—	26
40—44	—	—	—	—	4	1	—	5	5	4	5	3	2	—	1	30
45—49	—	—	—	1	1	—	1	4	3	1	4	—	1	—	—	16
50—54	—	—	—	—	—	2	2	4	2	3	3	3	2	—	—	21
55—59	1	—	—	—	—	3	3	3	5	6	4	3	—	—	—	28
60—64	—	—	1	—	—	—	2	6	7	—	4	5	—	—	—	25
65—69	—	—	—	—	1	—	1	6	1	1	2	—	—	—	—	12
70—74	—	—	—	—	—	3	1	3	3	1	2	1	—	—	—	14
75—79	—	—	—	—	—	—	—	2	3	1	—	—	—	—	—	6
Totals	1	—	2	1	6	14	14	44	40	30	38	28	11	1	3	233

TABLE 11.

Swedes. Stature and Age. "Young" Series. Males.

Stature (centimetres).

Age (years).		144—146	147—149	150—152	153—155	156—158	159—161	162—164.	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188	189—191	Totals
	20—24	—	—	—	—	—	1	3	1	5	4	7	3	2	1	—	1	27
	25—29	—	—	—	—	—	1	1	7	4	6	6	10	1	1	—	—	37
	30—34	—	—	1	—	1	2	5	9	12	6	6	4	—	2	—	—	48
	35—39	1	—	—	1	—	5	4	12	9	6	3	6	2	—	—	—	49
	40—44	—	—	1	—	1	6	8	12	9	11	5	5	3	—	—	—	61
	45—49	1	—	—	—	1	4	8	5	6	5	5	4	—	1	—	—	40
	Totals	2	—	2	1	3	18	29	46	45	38	32	32	8	5	—	1	262

TABLE 12.

Swedes. Stature and Age. "Young" Series. Females.

Stature (centimetres).

Age (years).		138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	Totals
	20—24	—	—	—	—	—	1	3	4	6	2	1	—	1	18
	25—29	1	—	—	—	—	3	4	1	2	2	4	—	—	17
	30—34	—	—	—	3	2	3	1	2	—	7	—	1	1	20
	35—39	—	—	—	2	2	4	3	6	6	2	1	—	—	26
	40—44	—	—	4	1	—	5	5	4	5	3	2	—	1	30
	45—49	—	1	1	—	1	4	3	1	4	—	1	—	—	16
	Totals	1	1	5	6	5	20	19	18	23	16	9	1	3	127

TABLE 13.

Hessians. Brain-weight and Stature. "Total" Series. Males.

Stature (centimetres).

Brain-weight (grams).																			Totals
	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188	189—191	
1000—1049	—	—	—	—	—	—	—	2	—	—	1	—	—	1	—	—	—	—	4
1050—1099	1	—	—	—	—	1	—	1	—	—	—	—	—	—	—	—	—	—	3
1100—1149	—	1	—	—	—	—	—	3	—	—	1	1	—	—	1	—	—	—	7
1150—1199	—	—	—	—	—	—	2	—	1	2	—	2	—	—	—	—	—	—	8
1200—1249	—	—	—	—	1	—	1	3	3	3	1	4	1	1	1	—	—	—	19
1250—1299	—	—	—	—	1	4	6	7	5	8	6	5	5	1	—	1	—	—	49
1300—1349	—	—	—	1	2	4	8	10	14	8	18	8	6	5	—	—	—	1	85
1350—1399	1	—	—	—	1	—	4	6	9	10	11	14	7	3	1	—	—	—	67
1400—1449	—	—	—	1	1	1	4	5	12	13	19	16	8	2	—	3	—	—	85
1450—1499	—	1	1	—	—	—	2	2	9	11	7	17	2	5	2	—	—	—	59
1500—1549	—	—	—	—	—	3	2	4	7	10	14	9	3	3	1	1	—	—	57
1550—1599	—	—	—	—	—	1	1	1	3	4	3	8	3	1	1	—	—	—	26
1600—1649	—	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	—	—	3
1650—1699	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	—	—	2
1700—1749	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
Totals	2	2	1	2	6	14	30	45	63	73	82	85	35	22	7	5	—	1	475

TABLE 14.

Hessians. Brain-weight and Stature. "Total" Series. Females.

Stature (centimetres).

Brain-weight (grams).																			Totals	
	126—128	129—131	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179		180—182
950—999	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1
1000—1049	1	—	—	—	—	—	—	1	—	1	2	1	—	—	—	—	—	—	—	6
1050—1099	—	—	—	—	1	—	1	1	1	1	4	3	—	—	—	—	—	—	—	12
1100—1149	—	—	—	—	—	—	—	2	3	3	3	3	1	—	1	—	—	—	—	21
1150—1199	—	—	—	—	—	2	—	5	5	9	3	5	1	1	—	—	—	—	—	31
1200—1249	—	—	—	—	1	1	4	5	3	9	19	10	6	2	1	1	—	—	—	62
1250—1299	—	—	—	—	1	1	—	3	4	9	14	9	5	3	5	3	—	—	—	56
1300—1349	—	—	—	—	—	—	1	1	6	8	6	7	4	2	1	—	—	—	—	36
1350—1399	—	—	—	1	—	1	—	3	6	4	5	4	1	1	1	—	—	—	—	27
1400—1449	—	—	—	—	1	—	1	2	4	1	4	3	3	1	—	1	1	—	—	23
1450—1499	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	3
1500—1549	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	3
Totals	1	—	—	1	3	7	7	23	32	46	65	45	25	10	9	5	1	—	1	281

TABLE 15.

Hessians. Brain-weight and Stature. "Young" Series. Males.

15—50 years.

Stature (centimetres).

Brain-weight (grams).	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	Totals
1000—1049	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	2
1500—1099	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
1100—1149	—	1	—	—	—	—	—	1	—	—	1	1	—	—	1	—	5
1150—1199	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	2
1200—1249	—	—	—	—	—	—	—	1	1	2	—	2	—	—	—	—	7
1250—1299	—	—	—	—	1	2	4	3	2	7	2	2	3	1	—	1	28
1300—1349	—	—	—	1	—	3	3	6	10	5	10	6	4	4	—	—	52
1350—1399	1	—	—	—	1	—	3	4	4	7	8	11	2	—	—	—	41
1400—1449	—	—	—	1	1	1	2	2	7	5	9	8	3	1	—	3	43
1450—1499	—	1	1	—	—	—	2	2	7	9	6	12	2	2	2	—	46
1500—1549	—	—	—	—	—	2	1	4	3	7	11	6	2	1	—	—	37
1550—1599	—	—	—	—	—	—	1	—	2	4	2	8	3	1	1	—	22
1600—1649	—	—	—	—	—	—	—	—	—	2	1	—	—	—	—	—	3
1650—1699	—	—	—	—	—	—	—	—	—	1	—	1	—	—	—	—	2
Totals	1	2	1	2	3	8	17	26	36	50	50	58	19	10	4	4	291

TABLE 16.

Hessians. Brain-weight and Stature. "Young" Series. Females.

15—50 years.

Stature (centimetres).

Brain-weight (grams).	128—128	129—131	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	Totals
1000—1049	1	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	3
1050—1099	—	—	—	—	1	—	—	—	1	—	2	2	—	—	—	—	—	—	—	6
1100—1149	—	—	—	—	—	1	—	—	1	—	3	2	—	—	—	—	—	—	—	7
1150—1199	—	—	—	—	—	1	—	3	1	4	3	1	1	1	—	—	—	—	—	15
1200—1249	—	—	—	—	1	1	3	2	2	4	14	4	6	1	—	1	—	—	—	39
1250—1299	—	—	—	—	—	—	—	2	3	5	11	6	2	2	2	3	—	—	—	36
1300—1349	—	—	—	—	—	—	—	1	4	5	1	5	3	2	1	—	—	—	—	22
1350—1399	—	—	—	1	—	1	—	2	4	2	3	3	1	1	1	—	—	—	—	19
1400—1449	—	—	—	—	1	—	1	2	4	1	2	3	3	—	—	1	1	—	1	20
1450—1499	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	3
1500—1549	—	—	—	—	—	—	—	—	—	1	1	—	1	—	—	—	—	—	—	3
Totals	1	—	—	1	3	4	4	13	20	22	41	26	20	7	4	5	1	—	1	173

TABLE 17.

Hessians. Brain-weight and Age. "Total" Series. Males.

Brain-weight (grams).

Age (years).	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	1700—1749	Totals
15—19	—	—	1	—	—	2	8	4	10	5	4	2	—	—	—	36
20—24	—	1	1	1	—	2	7	9	6	15	10	5	1	—	—	58
25—29	—	—	1	—	1	6	14	6	6	8	7	1	1	1	—	52
30—34	—	—	1	—	5	2	4	5	9	5	6	3	—	1	—	41
35—39	—	—	—	1	—	6	5	2	6	1	1	2	—	—	—	24
40—44	1	—	—	—	1	4	6	14	1	6	5	4	—	—	—	42
45—49	1	—	1	—	—	6	8	1	5	6	4	5	1	—	—	38
50—54	1	1	—	2	6	6	8	2	17	3	8	—	—	—	1	55
55—59	—	—	1	2	—	5	6	10	8	3	5	1	—	—	—	41
60—64	1	1	—	—	2	1	5	6	12	2	3	—	—	—	—	33
65—69	—	—	—	2	1	4	8	4	3	4	3	1	—	—	—	30
70—74	—	—	1	—	3	2	4	2	1	1	1	2	—	—	—	17
75—79	—	—	—	—	—	3	2	2	1	—	—	—	—	—	—	8
Totals	4	3	7	8	19	49	85	67	85	59	57	26	3	2	1	475

TABLE 18.

Hessians. Brain-weight and Age. "Total" Series. Females.

Brain-weight (grams).

Age (years).	950—999	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	Totals
15—19	—	—	1	—	2	4	2	—	—	7	1	—	17
20—24	—	—	1	—	1	5	9	1	2	1	1	1	22
25—29	—	—	1	1	2	4	3	6	4	4	—	1	26
30—34	—	—	—	3	2	6	2	—	3	1	—	1	18
35—39	—	—	3	—	4	5	5	6	6	2	1	—	32
40—44	—	1	—	2	1	6	10	7	2	2	—	—	31
45—49	—	2	—	1	3	9	5	2	2	3	—	—	27
50—54	—	—	—	2	3	8	4	4	5	1	—	—	27
55—59	—	—	2	3	2	5	3	5	3	2	—	—	25
60—64	—	—	2	3	2	3	5	1	—	—	—	—	16
65—69	—	—	1	—	4	4	5	2	—	—	—	—	16
70—74	1	2	1	5	3	3	3	2	—	—	—	—	20
75—79	—	1	—	1	2	—	—	—	—	—	—	—	4
Totals	1	6	12	21	31	62	56	36	27	23	3	3	281

TABLE 19.

Hessians. Brain-weight and Age. "Young" Series. Males.

Brain-weight (grams).

Age (years).	Brain-weight (grams)														Totals
	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	
15—19	—	—	1	—	—	2	8	4	10	5	4	2	—	—	36
20—24	—	1	1	1	—	2	7	4	6	15	10	5	1	—	58
25—29	—	—	1	—	—	6	14	6	6	8	7	1	1	1	52
30—34	—	—	1	—	5	2	4	5	9	5	6	3	—	1	41
35—39	—	—	—	1	—	6	5	2	6	1	1	2	—	—	24
40—44	1	—	—	—	1	4	6	14	1	6	5	4	—	—	42
45—49	1	—	1	—	—	6	8	1	5	6	4	5	1	—	38
Totals	2	1	5	2	7	28	52	41	43	46	37	22	3	2	291

TABLE 20.

Hessians. Brain-weight and Age. "Young" Series. Females.

Brain-weight (grams).

Age (years).	Brain-weight (grams)											Totals
	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	
15—19	—	1	—	2	4	2	—	—	7	1	—	17
20—24	—	1	—	1	5	9	1	2	1	1	1	22
25—29	—	1	1	2	4	3	6	4	4	—	1	26
30—34	—	—	3	2	6	2	—	3	1	—	1	18
35—39	—	3	—	4	5	5	6	6	2	1	—	32
40—44	1	—	2	1	6	10	7	2	2	—	—	31
45—49	2	—	1	3	9	5	2	2	3	—	—	27
Totals	3	6	7	15	39	36	22	19	20	3	3	173

TABLE 21.

Hessians. Stature and Age. "Total" Series. Males.

Stature (centimetres).

	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—188	189—191	Totals
Age (years).																			
15—19	1	2	1	2	1	4	4	4	4	3	5	2	2	1	—	—	—	—	36
20—24	—	—	—	—	—	1	—	6	6	8	18	10	2	4	—	—	—	—	58
25—29	—	—	—	—	—	—	6	7	8	8	11	3	3	1	—	—	—	—	52
30—34	—	—	—	—	1	1	—	2	6	9	2	12	3	1	2	2	—	—	41
35—39	—	—	—	—	—	—	2	—	3	5	4	6	2	1	—	1	—	—	24
40—44	—	—	—	—	1	1	4	5	3	6	7	9	3	1	1	1	—	—	42
45—49	—	—	—	—	—	1	1	2	4	10	6	8	4	1	1	—	—	—	38
50—54	1	—	—	—	1	1	3	3	8	11	4	11	6	4	1	1	—	—	55
55—59	—	—	—	—	—	—	3	3	4	4	11	5	5	4	1	—	—	1	41
60—64	—	—	—	—	—	1	1	4	4	2	9	7	3	2	—	—	—	—	33
65—69	—	—	—	—	1	3	3	2	6	3	4	3	2	2	1	—	—	—	30
70—74	—	—	—	—	1	1	1	5	4	2	3	—	—	—	—	—	—	—	17
75—79	—	—	—	—	—	—	2	2	1	1	1	1	—	—	—	—	—	—	8
Totals	2	2	1	2	6	14	30	45	63	73	82	85	35	22	7	5	—	1	475

TABLE 22.

Hessians. Stature and Age. "Total" Series. Females.

Stature (centimetres).

	126—128	129—131	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	Totals
Age (years).																				
15—19	—	—	—	—	2	—	—	3	3	1	3	1	2	—	1	1	—	—	—	17
20—24	—	—	—	—	—	—	—	—	7	6	7	3	4	—	1	1	—	—	—	22
25—29	—	—	—	1	—	1	—	—	—	2	5	2	5	1	1	1	1	—	—	26
30—34	—	—	—	—	—	1	—	1	2	2	5	2	2	1	—	2	—	—	—	18
35—39	—	—	—	—	1	2	1	4	1	4	7	7	4	—	—	1	—	—	—	32
40—44	—	—	—	—	—	—	1	4	3	3	7	7	1	3	1	—	—	—	—	31
45—49	1	—	—	—	—	—	2	1	4	4	7	4	2	2	—	—	—	—	—	27
50—54	—	—	—	—	—	—	—	5	4	4	8	4	—	—	2	—	—	—	—	27
55—59	—	—	—	—	—	—	2	—	—	6	6	6	1	2	2	—	—	—	—	25
60—64	—	—	—	—	—	—	—	1	1	5	3	3	2	—	1	—	—	—	—	16
65—69	—	—	—	—	—	1	1	—	3	3	5	2	—	1	—	—	—	—	—	16
70—74	—	—	—	—	—	2	—	3	4	4	2	3	2	—	—	—	—	—	—	20
75—79	—	—	—	—	—	—	—	1	—	2	—	1	—	—	—	—	—	—	—	4
Totals	1	—	—	1	3	7	7	23	32	46	65	45	25	10	9	5	1	—	1	281

TABLE 23.

Hessians. Stature and Age. "Young" Series. Males.

15—50 years.

Stature (centimetres).

Age (years).																	Totals
	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	
15—19	1	2	1	2	1	4	4	4	4	3	5	2	2	1	—	—	36
20—24	—	—	—	—	—	1	—	6	8	9	18	10	2	4	—	—	58
25—29	—	—	—	—	—	—	6	7	8	8	8	11	3	1	—	—	52
30—34	—	—	—	—	1	1	—	2	6	9	2	12	3	1	2	2	41
35—39	—	—	—	—	—	—	2	—	3	5	4	6	2	1	—	1	24
40—44	—	—	—	—	1	1	4	5	3	6	7	9	3	1	1	1	42
45—49	—	—	—	—	—	1	1	2	4	10	6	8	4	1	1	—	38
Totals	1	2	1	2	3	8	17	26	36	50	50	58	19	10	4	4	291

TABLE 24.

Hessians. Stature and Age. "Young" Series. Females.

15—50 years.

Stature (centimetres).

Age (years).		126—128	129—131	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	Totals
15—19	—	—	—	—	2	—	—	—	3	3	1	3	1	2	—	1	1	—	—	—	17
20—24	—	—	—	—	—	—	—	—	—	6	7	7	3	4	—	1	—	1	—	—	22
25—29	—	—	—	1	—	—	1	—	—	2	2	5	2	5	1	1	1	—	—	—	26
30—34	—	—	—	—	—	—	1	—	1	2	2	5	2	2	1	—	2	—	—	—	18
35—39	—	—	—	—	1	2	1	1	4	1	4	7	7	4	—	—	1	—	—	—	32
40—44	—	—	—	—	—	—	1	1	4	3	3	7	7	1	3	1	—	—	—	1	31
45—49	1	—	—	—	—	—	—	2	1	4	4	7	4	2	2	—	—	—	—	—	27
Totals	1	—	—	1	3	4	4	4	13	20	22	41	26	20	7	4	5	1	—	1	173

TABLE 25.

Bohemians. Brain-weight and Stature.
 "Young" Series. Males. 20—59 years.

Brain-weight (grams).

Stature (centimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	1600—1699	1700—1799	Totals
150—154	—	—	—	1	—	—	—	—	1
155—159	1	1	4	4	4	1	—	—	15
160—164	—	5	15	22	9	2	1	—	54
165—169	—	3	15	24	17	7	—	—	66
170—174	—	5	17	21	21	2	2	1	69
175—179	—	3	7	9	10	5	2	—	36
180—184	—	1	—	7	4	2	—	1	15
185—189	—	—	2	—	2	—	—	—	4
190—194	—	—	—	—	—	1	—	—	1
Totals	1	19	63	88	68	20	5	2	266

TABLE 26.

Bohemians. Brain-weight and Stature.
 "Young" Series. Females. 20—59 years.

Brain-weight (grams).

Stature (centimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	Totals
130—134	—	—	1	—	—	—	1
135—139	—	—	—	1	—	—	1
140—144	—	—	—	2	—	—	2
145—149	—	2	7	5	2	—	16
150—154	1	—	11	6	4	—	22
155—159	2	4	19	14	2	1	42
160—164	—	3	6	14	7	2	32
165—169	—	—	2	5	4	—	11
170—174	—	—	2	2	1	—	5
175—179	—	—	—	—	1	—	1
Totals	3	9	48	49	21	3	133

TABLE 27.

Bohemians. Brain-weight and Age.
 "Total" Series. Males.

Brain-weight (grams).

Age (years).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	1600—1699	1700—1799	Totals
20—29	—	4	12	28	21	9	2	1	77
30—39	—	5	12	17	14	6	3	1	58
40—49	1	10	24	27	23	6	—	—	91
50—59	—	3	19	31	19	4	1	—	77
60—69	—	4	17	11	9	4	1	—	46
70—79	—	1	14	8	—	—	—	—	23
Totals	1	27	98	122	86	29	7	2	372

TABLE 28.

Bohemians. Brain-weight and Age.
 "Total" Series. Females.

Brain-weight (grams).

Age (years).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	Totals
20—29	1	2	28	26	13	2	72
30—39	—	2	9	14	7	3	35
40—49	1	4	8	10	7	—	30
50—59	1	2	14	6	2	1	26
60—69	—	4	10	5	—	—	19
70—79	—	5	4	4	2	—	15
Totals	3	19	73	65	31	6	197

TABLE 29.

Bohemians. Brain-weight and Skull Length.
Males. 20—59 years.

Brain-weight (grams).

Skull length (millimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	1600—1699	1700—1799	1800—1899	Totals
155—159	—	—	1	1	—	—	—	—	—	2
160—164	—	—	2	6	4	2	—	—	—	14
165—169	1	—	9	10	18	3	—	—	—	42
170—174	—	—	5	19	28	11	4	1	—	68
175—179	—	—	4	19	29	23	4	—	—	79
180—184	—	—	—	10	19	23	8	1	—	61
185—189	—	—	—	1	2	12	4	—	—	19
190—194	—	—	—	—	1	2	3	4	—	10
195—199	—	—	—	—	—	1	1	—	2	4
Totals	1	—	21	66	101	77	25	6	2	299

TABLE 30.

Bohemians. Brain-weight and Skull Length.
Females. 20—59 years.

Brain-weight (grams).

Skull length (millimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	Totals
150—154	—	1	—	—	—	1	2
155—159	—	2	1	—	—	—	3
160—164	1	1	18	4	3	—	27
165—169	—	4	16	9	3	1	33
170—174	1	2	18	33	14	3	71
175—179	—	—	6	4	7	—	17
180—184	—	—	—	4	1	1	6
Totals	2	10	59	54	28	6	159

TABLE 31.

Bohemians. Brain-weight and Skull Breadth.
Males. 20—59 years.

Brain-weight (grams).

Skull breadth (millimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	1600—1699	1700—1799	1800—1899	Totals
110—114	—	—	—	—	—	1	—	—	—	1
115—119	—	—	—	—	—	—	—	—	—	—
120—124	—	—	—	—	—	—	—	—	—	—
125—129	—	—	—	—	—	—	—	—	—	—
130—134	—	—	—	—	2	1	—	—	—	3
135—139	—	—	4	2	1	1	—	—	—	8
140—144	1	—	8	19	21	7	1	1	—	58
145—149	—	—	8	21	32	17	—	—	—	78
150—154	—	—	1	22	35	26	11	—	—	95
155—159	—	—	—	2	9	14	11	2	2	40
160—164	—	—	—	—	1	6	2	2	—	11
165—169	—	—	—	—	—	3	—	1	—	4
170—174	—	—	—	—	—	—	—	—	—	—
175—179	—	—	—	—	—	1	—	—	—	1
Totals	1	—	21	66	101	77	25	6	2	299

TABLE 32.

Bohemians. Brain-weight and Skull Breadth.
Females. 20—59 years.

Brain-weight (grams).

Skull breadth (millimetres).	1000—1099	1100—1199	1200—1299	1300—1399	1400—1499	1500—1599	Totals
130—134	—	—	4	1	—	—	6
135—139	2	4	9	5	—	—	20
140—144	—	6	28	19	7	—	60
145—149	—	—	14	20	6	4	44
150—154	—	—	4	6	11	1	22
155—159	—	—	—	2	3	1	6
160—164	—	—	—	1	—	—	1
Total	2	10	59	54	28	6	159

Variation and Correlation in Brain-Weight

TABLE 33.

Bohemians. Skull Length and Skull Breadth. Males.

20—59 years.

Skull length (millimetres).

Skull breadth (millimetres).	Skull length (millimetres).									Totals
	155—159	160—164	165—169	170—174	175—179	180—184	185—189	190—194	195—199	
110—114	—	—	—	1	—	—	—	—	—	1
115—119	—	—	—	—	—	—	—	—	—	—
120—124	—	—	—	—	—	—	—	—	—	—
125—129	—	—	—	—	—	—	—	—	—	—
130—134	—	—	2	—	—	1	—	—	—	3
135—139	—	1	3	3	1	—	—	—	—	8
140—144	—	6	12	14	8	17	1	—	—	58
145—149	2	5	14	17	24	10	5	1	—	78
150—154	—	2	10	25	30	20	6	2	—	95
155—159	—	—	1	5	11	11	5	4	3	40
160—164	—	—	—	3	5	1	—	2	—	11
165—169	—	—	—	—	—	1	2	1	—	4
170—174	—	—	—	—	—	—	—	—	—	—
175—179	—	—	—	—	—	—	—	—	1	1
Totals	2	14	42	68	79	61	19	10	4	299

TABLE 34.

Bohemians. Skull Length and Skull Breadth. Females.

20—59 years.

Skull length (millimetres).

Skull breadth (millimetres).	Skull length (millimetres).							Totals
	150—154	155—159	160—164	165—169	170—174	175—179	180—184	
130—134	—	1	1	—	3	1	—	6
135—139	1	1	4	4	7	2	1	20
140—144	—	1	15	13	25	5	1	60
145—149	1	—	3	12	20	6	2	44
150—154	—	—	4	3	11	2	2	22
155—159	—	—	—	1	4	1	—	6
160—164	—	—	—	—	1	—	—	1
Totals	2	3	27	33	71	17	6	159

TABLE 35.

Bavarians. Brain-weight and Stature. "Total," Short Series. Males.

Stature (centimetres).

Brain-weight (grams).																Totals
	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185	186—189	
1000—1049	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	2
1050—1099	—	—	—	—	—	1	1	—	2	—	—	—	—	—	—	4
1100—1149	—	—	—	—	1	—	—	1	2	—	—	—	—	—	—	4
1150—1199	—	1	—	1	2	3	—	1	1	1	1	—	—	—	—	11
1200—1249	—	—	1	2	3	6	6	11	4	1	2	1	1	—	—	38
1250—1299	—	—	—	1	4	7	6	9	13	5	5	1	—	—	—	51
1300—1349	—	—	—	3	6	10	7	18	11	3	—	4	—	—	—	62
1350—1399	—	—	1	3	5	6	12	13	16	7	8	1	1	1	—	74
1400—1449	1	—	2	1	2	5	4	14	10	5	2	2	1	—	—	49
1450—1499	—	—	—	1	4	—	5	8	5	6	2	2	—	—	—	33
1500—1549	—	—	—	—	2	1	—	5	4	1	6	1	—	—	1	21
1550—1599	—	—	—	—	1	—	—	—	3	1	1	2	—	—	—	8
1600—1649	—	—	—	—	—	—	2	3	1	—	—	—	—	—	—	6
1650—1699	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—	2
Totals	1	1	4	12	31	39	44	83	72	31	28	14	3	1	1	365

TABLE 36.

Bavarians. Brain-weight and Stature. "Total," Short Series. Females.

Stature (centimetres).

Brain-weight (grams).	Stature (centimetres).														Totals	
	132—134	135—137	138—140	141—143	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173		174—177
800— 849	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	2
850— 899	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
900— 949	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1
950— 999	—	—	—	—	—	1	—	—	2	—	—	—	—	—	—	4
1000—1049	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	2
1050—1099	—	—	—	—	1	3	2	2	4	2	—	—	—	—	1	15
1100—1149	—	—	—	1	3	6	7	6	7	3	2	—	—	—	—	35
1150—1199	—	—	—	1	2	4	9	4	15	4	2	—	—	—	1	42
1200—1249	—	1	1	—	4	5	7	9	10	8	1	1	—	—	—	47
1250—1299	1	—	—	—	6	6	13	5	9	7	3	—	1	—	—	51
1300—1349	—	—	—	—	1	4	1	6	1	3	1	1	1	—	—	19
1350—1399	—	—	—	—	—	1	1	1	4	6	1	—	—	—	—	14
1400—1449	—	—	—	—	—	—	—	1	2	1	—	—	—	—	—	4
1450—1499	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1
1500—1549	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	3
1550—1599	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Totals	2	1	1	2	17	31	41	36	54	37	11	3	2	—	3	241

TABLE 37.

Bavarians. Brain-weight and Age. "Total," Long Series. Males.

Brain-weight (grams).

	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	Totals
Age (years).															
20—24	—	—	—	1	3	3	6	10	5	1	3	—	—	—	32
25—29	—	—	—	—	6	7	8	15	8	5	—	3	2	—	54
30—34	—	1	—	2	7	12	10	18	9	7	2	6	3	1	78
35—39	—	2	1	4	10	14	22	14	16	7	8	3	1	2	104
40—44	—	1	—	—	7	5	4	11	13	8	2	—	1	—	52
45—49	—	—	1	—	5	6	9	10	3	6	3	1	1	—	45
50—54	—	—	—	1	5	10	7	14	9	4	3	2	3	—	58
55—59	—	—	1	1	3	4	8	8	6	1	3	—	—	2	37
60—64	—	—	—	2	6	2	2	6	4	3	1	—	1	—	27
65—69	1	—	—	2	1	3	6	4	1	1	—	—	—	—	19
70—74	—	—	1	2	—	5	2	2	2	1	—	—	—	—	15
75—79	1	—	—	1	1	3	—	1	—	1	—	—	—	—	8
Totals	2	4	4	16	54	74	84	113	76	45	25	15	12	5	529

TABLE 38.

Bavarians. Brain-weight and Age. "Total," Long Series. Females.

Brain-weight (grams).

	800—849	850—899	900—949	950—999	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	Totals
Age (years).																	
20—24	—	—	—	—	—	6	2	10	9	11	7	1	—	—	—	1	47
25—29	—	—	—	—	—	6	6	13	9	14	3	3	1	1	—	—	51
30—34	—	—	—	—	1	1	6	13	15	7	4	3	1	—	—	—	51
35—39	—	—	—	—	—	6	1	4	9	13	7	3	2	—	—	—	45
40—44	—	—	—	—	—	1	2	2	5	4	2	2	1	—	2	—	21
45—49	—	—	—	1	—	—	5	3	7	6	—	1	—	—	—	—	23
50—54	1	—	—	1	—	3	6	4	6	4	1	2	—	—	—	—	28
55—59	—	—	—	—	—	—	1	1	2	5	—	—	1	—	—	—	10
60—64	—	—	—	1	1	1	4	1	3	2	2	2	—	—	—	—	17
65—69	—	—	1	—	2	1	3	3	1	3	—	1	—	—	—	—	15
70—74	1	—	—	—	—	3	1	1	2	—	—	1	—	—	—	—	9
75—79	—	—	—	1	—	—	4	1	—	—	—	—	—	—	—	—	6
Totals	2	—	1	4	4	22	41	56	68	69	26	19	6	1	3	1	323

TABLE 39.

Bavarians. Brain-weight and Age. "Young," Long Series. Males.

Brain-weight (grams).

Age (years).	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	1600—1649	1650—1699	Totals
20—24	—	—	1	3	3	6	10	5	1	3	—	—	—	32
25—29	—	—	—	6	7	8	15	8	5	—	3	2	—	54
30—34	1	—	2	7	12	10	18	9	7	2	6	3	1	78
35—39	2	1	4	10	14	22	14	16	8	3	1	1	2	104
40—44	1	—	—	7	5	4	11	13	8	2	—	1	—	52
45—49	—	1	—	5	6	9	10	3	6	3	1	1	—	45
Totals	4	2	7	38	47	59	78	54	34	18	13	8	3	365

TABLE 40.

Bavarians. Brain-weight and Age. "Young," Long Series. Females.

Brain-weight (grams).

Age (years).	950—999	1000—1049	1050—1099	1100—1149	1150—1199	1200—1249	1250—1299	1300—1349	1350—1399	1400—1449	1450—1499	1500—1549	1550—1599	Totals
20—24	—	—	6	2	10	9	11	7	1	—	—	—	1	47
25—29	—	—	—	6	13	9	14	3	3	1	1	—	—	51
30—34	—	1	1	6	13	15	7	4	3	1	—	—	—	51
35—39	—	—	6	1	4	9	13	7	3	2	—	—	—	45
40—44	—	—	1	2	2	5	4	2	2	1	—	2	—	21
45—49	1	—	—	5	3	7	6	—	1	—	—	—	—	23
Totals	1	1	14	22	45	54	55	23	13	5	1	3	1	238

TABLE 41.

Bavarians. Brain-weight and Body-weight. "Total," Short Series. Males.

Body-weight (kilograms).

Brain-weight (grams).	Body-weight (kilograms).														Totals
	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	
1000-1049	—	—	1	—	1	—	—	—	—	—	—	—	—	—	2
1050-1099	—	—	—	2	1	—	1	—	—	—	—	—	—	—	4
1100-1149	—	—	—	2	1	1	—	—	—	—	—	—	—	—	4
1150-1199	—	2	—	4	2	1	1	1	—	—	—	—	—	—	11
1200-1249	—	5	9	7	7	5	3	2	—	—	—	—	—	—	38
1250-1299	—	1	4	12	10	8	7	2	2	3	1	1	—	—	51
1300-1349	—	2	8	16	10	13	7	5	—	1	—	—	—	—	62
1350-1399	1	1	8	9	18	10	11	9	2	3	—	1	—	1	74
1400-1449	—	3	7	5	12	5	4	7	4	2	—	—	—	—	49
1450-1499	—	2	2	7	6	5	6	1	4	—	—	—	—	—	33
1500-1549	—	2	2	2	5	1	3	2	1	1	1	—	—	1	21
1550-1599	—	—	—	1	1	2	1	2	1	—	—	—	—	—	8
1600-1649	—	—	1	2	2	—	1	—	—	—	—	—	—	—	6
1650-1699	—	—	1	—	—	—	—	—	—	—	1	—	—	—	2
Totals	1	18	43	69	76	51	45	31	14	10	3	2	—	2	365

TABLE 42.

Bavarians. Brain-weight and Body-weight. "Total," Short Series. Females.

Body-weight (kilograms).

Brain-weight (grams).	Body-weight (kilograms).															Totals
	15—19	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—90	
800—849	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2
850—899	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
900—949	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
950—999	—	—	1	—	1	—	—	1	—	—	—	1	—	—	—	4
1000—1049	—	—	1	—	—	1	—	—	—	—	—	—	—	—	—	2
1050—1099	—	—	2	3	5	3	1	—	1	—	—	—	—	—	—	15
1100—1149	—	1	1	8	7	9	3	3	—	2	—	—	—	—	1	35
1150—1199	—	—	8	6	9	5	8	2	3	1	—	—	—	—	—	42
1200—1249	1	—	—	5	10	6	12	5	5	1	1	1	—	—	—	47
1250—1299	—	1	5	4	11	10	10	6	3	1	—	—	—	—	—	51
1300—1349	—	—	—	1	7	3	2	2	1	2	—	1	—	—	—	19
1350—1399	—	—	2	1	2	3	4	—	1	—	1	—	—	—	—	14
1400—1449	—	—	—	—	2	—	1	—	—	—	—	1	—	—	—	4
1450—1499	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1
1500—1549	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	3
1550—1599	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
Totals	1	2	22	28	54	40	42	22	14	8	3	4	—	—	1	241

TABLE 43.

Bavarians. Body-weight and Stature. "Total," Short Series. Males.

Stature (centimetres).

Body-weight (kilograms).															Totals	
	144—146	147—149	150—152	153—155	156—158	159—161	162—164	165—167	168—170	171—173	174—176	177—179	180—182	183—185		186—188
25—29	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	1
30—34	—	—	—	2	5	4	1	4	2	—	—	—	—	—	—	18
35—39	1	—	3	—	4	7	7	16	3	2	—	—	—	—	—	43
40—44	—	1	—	7	8	9	5	19	12	4	1	2	1	—	—	69
45—49	—	—	1	1	5	5	17	17	15	3	6	6	—	—	—	76
50—54	—	—	—	—	4	9	4	13	10	7	3	3	1	—	—	51
55—59	—	—	—	1	2	4	3	7	16	6	2	1	2	—	1	45
60—64	—	—	—	1	1	—	4	4	8	4	5	3	—	1	—	31
65—69	—	—	—	—	—	—	1	1	3	3	6	—	—	—	—	14
70—74	—	—	—	—	1	1	1	2	3	—	1	1	—	—	—	10
75—79	—	—	—	—	—	—	—	—	—	1	2	—	—	—	—	3
80—84	—	—	—	—	—	—	1	—	—	—	1	—	—	—	—	2
85—89	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
90—94	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	2
Totals	1	1	4	12	31	39	44	83	72	31	28	14	3	1	1	365

TABLE 44.

Bavarians. Body-weight and Stature. "Total," Short Series. Females.

Body-weight (kilograms).

Stature (centimetres).	Body-weight (kilograms).															Totals
	15—19	20—24	25—29	30—34	35—39	40—44	45—49	50—54	55—59	60—64	65—69	70—74	75—79	80—84	85—90	
132—134	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	2
135—137	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
138—140	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
141—143	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	2
144—146	—	1	3	4	5	1	3	—	—	—	—	—	—	—	—	17
147—149	—	1	7	5	6	4	6	1	—	1	—	—	—	—	—	31
150—152	—	—	2	9	11	9	5	3	1	1	—	—	—	—	—	41
153—155	—	—	2	2	12	5	5	3	4	1	1	1	—	—	—	36
156—158	—	—	2	5	12	11	11	8	3	—	2	—	—	—	—	54
159—161	—	—	1	1	5	8	8	7	6	1	—	—	—	—	—	37
162—164	—	—	2	—	2	1	2	—	—	2	1	—	—	—	1	11
165—167	—	—	—	1	—	—	—	—	—	1	—	1	—	—	—	3
168—170	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	2
171—173	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
174—177	—	—	—	—	1	—	—	—	—	1	1	—	—	—	—	3
Totals	1	2	22	28	54	40	42	22	14	8	3	4	—	—	1	241

TABLE 45.

English. Weight of Cerebrum and Stature. Males.

Stature (inches).

	Stature (inches).															Totals
	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	
28	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	1
29	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	2
30	—	—	—	—	1	—	—	—	—	1	1	1	—	—	—	4
31	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
32	—	—	—	—	2	—	—	1	—	—	—	—	—	—	—	3
33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
34	—	—	—	1	—	1	2	—	1	—	—	—	1	—	2	8
35	—	—	—	—	—	1	—	4	4	—	1	—	1	—	1	12
36	—	—	—	—	—	—	2	—	2	2	2	—	3	—	1	12
37	—	—	—	—	—	1	—	4	1	3	2	2	1	—	—	14
38	1	—	1	—	—	1	2	1	5	6	4	3	3	—	—	27
39	—	—	1	—	1	1	1	2	5	—	2	3	2	—	—	18
40	—	—	—	—	—	—	1	3	4	4	5	2	2	—	1	22
41	—	—	1	1	—	1	3	2	2	4	3	3	5	3	2	30
42	—	—	—	—	—	—	1	4	4	6	6	2	3	1	—	27
43	—	—	—	—	—	1	2	2	4	6	4	2	2	1	4	28
44	—	—	—	—	—	1	1	2	4	2	4	2	5	2	3	26
45	—	—	2	—	—	—	—	—	6	2	2	1	1	2	—	16
46	—	—	1	1	—	—	—	—	2	4	1	3	—	2	3	17
47	—	—	—	—	1	—	3	3	2	2	1	—	1	1	—	14
48	—	—	—	—	—	1	—	2	—	2	5	1	1	—	1	13
49	—	—	—	—	—	—	1	1	1	1	—	1	1	—	—	6
50	—	—	—	—	1	—	—	—	—	1	—	—	1	—	—	3
51	—	—	—	—	—	—	—	—	—	1	1	2	—	—	—	4
Totals	2	—	6	3	6	9	20	31	47	47	44	28	34	13	18	308

TABLE 46.

English. Weight of Cerebrum and Age. Males.

Weight of Cerebrum (ounces).

Age (years).		28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	Totals
	20—29	1	1	1	—	—	—	1	1	1	2	2	2	2	6	1	6	5	—	6	2	6	1	—	2	49
	30—39	—	—	1	—	—	—	3	2	3	2	3	3	4	4	3	5	4	5	4	4	2	3	—	—	55
	40—49	—	—	2	1	1	—	2	2	—	3	6	6	4	4	3	3	6	3	1	2	3	2	2	2	58
	50—59	—	—	—	—	—	—	—	—	4	2	2	4	8	4	6	4	4	2	4	4	1	—	—	—	49
	60—69	—	1	—	—	1	—	2	3	2	2	6	1	3	8	6	4	3	5	1	1	—	—	—	—	49
	70—79	—	—	—	—	1	—	—	4	2	3	8	2	1	4	8	6	4	1	1	1	1	—	1	—	48
	Totals	1	2	4	1	3	—	8	12	12	14	27	18	22	30	27	28	26	16	17	14	13	6	3	4	308