On the Laws of Inheritance in Man: I. Inheritance of Physical Characters

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ON THE LAWS OF INHERITANCE IN MAN*.

I. INHERITANCE OF PHYSICAL CHARACTERS.

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University College, London.

CONTENTS.

(i) *Introductory.*

ABOUT eight years ago I determined to supplement the data obtained by Mr Francis Galton for his work *Natural Inheritance* by a rather wider series of measurements on blood relations in man. Mr Galton had most generously placed his original data at my disposal and I had used them as far as stature was concerned in my memoir of 1895† and in a joint paper with Dr Lee in 1896‡. The eye-colour data of his Family Records were not reduced§ until after the discovery of a method for dealing with characters not capable of exact quantitative measurement‖, and it is only recently that the full scheme of relationships back to great-grandparents has been completed¶. There were about 200 families in Mr Galton's records and only one measurable character, stature. The conditions

* I must gratefully acknowledge aid in the publication of the elaborate tables which accompany this memoir from a grant made to my department in the University of London by the Worshipful Company of Drapers.

† "Regression, Heredity and Panmixia." *Phil. Trans.* Vol. 187, pp. 253—318.

‡ "On Telegony in Man." *R. S. Proc.* Vol. 60, p. 274 *et. seq.*

§ "On the Inheritance of Eye Colour in Man." *Phil. Trans.* Vol. 195, pp. 102—121.

‖ "On the Correlation of Characters not quantitatively Measurable." *Phil. Trans.* Vol. 195, pp. 1—47.

¶ F. E. Lutz: "Note on the Influence of Change in Sex on the Intensity of Heredity." *Biometrika*, Vol. II. pp. 237—240.

as to age of the measured, or to method of measurement were not, perhaps, as stringent as might now be considered desirable, but Mr Galton's data were amply sufficient to lead him to his great discovery of the general form of the inheritance of blending characters in a stable community. The full significance of this discovery is hardly yet understood, and one constantly notices grave misinterpretations of Mr Galton's theory in the works of non-statistically trained biologists. The constants as determined from Mr Galton's stature data did not seem to me to be final; they were to some extent irregular and were not in full accord with the more uniform eye-colour results. It therefore appeared to me desirable to obtain further data, not only for several physical characters and to compare the results for these characters with those for mental characters, but to deal with both in as wide as possible a system of blood relationships. This was provided for in the following series of observations:

I. *Family Record Series.* About 1893 I drew up in conjunction with my then colleague, W. F. R. Weldon, the directions for family measurement which are described below. The measurements were in great part carried out by college students*, and I largely owe the success of this series to the energy and time devoted to the collection of the data by Dr Alice Lee. In the course of four to five years about 1100 cards were filled in. The tabling of the data on these cards and the calculation of the statistical constants, some 78 tables in all, are due entirely to Dr Lee, and occupied her spare time for nearly two years.

II. *School Record Series.* This series was started some years later and was aided by a grant from the Government Grant Committee. Its object was to record the mental and physical characters in pairs of brothers, of sisters, and of sisters and brothers in schools. About six thousand children were observed and measured, and provided more than 3000 pairs of brethren to illustrate in a great variety of ways the intensity of collateral resemblance in man. This series will only be dealt with incidentally in the first part of this paper, about 150 of the tables have been formed and the correlations deduced from them, but much work remains still to be done on the data for schools.

III. *Cousinship Series.* A third series on the ten kinds of first cousins is now being started with aid from the Government Grant Committee to complete our quantitative conceptions of collateral heredity. But it will be a number of years before the data here desired can be fully collected and still longer before the reductions can be completed. The above series form the material from which it is proposed to obtain quantitative measures of the degree of resemblance between blood relations in man. The present memoir deals primarily with the Family Record Series.

(ii) *Nature of the Family Record Series.*

It seems desirable to give the actual form of the instructions and schedule by aid of which the data were collected.

* I must take this opportunity of most heartily thanking the many helpers, who devoted much time and energy to measuring not only single but often 10 or 20 families.

FAMILY MEASUREMENTS.

Professor KARL PEARSON, of University College, London, would esteem it a great favour if any persons in a position to do so, would assist him by making one set (or if possible several sets) of anthropometric measurements on their own family, or on families with whom they are acquainted. The measurements are to be made use of for testing theories of heredity, no names, except that of the recorder, are required, but the Professor trusts to the *bona fides* of each recorder to send only correct results.

Each family should consist of a father, mother, and at least one son or daughter, not necessarily the eldest. The sons or daughters are to be at least 18 years of age, and measurements are to be made on not more than two sons and two daughters of the same family. If more than two sons or two daughters are easily accessible, then not the tallest but the eldest of those accessible should be selected.

To be of real service the whole series ought to contain 1000—2000 families, and therefore the Professor will be only too grateful if anyone will undertake several families for him.

Copies of this paper, together with cards for recording data, may be obtained from

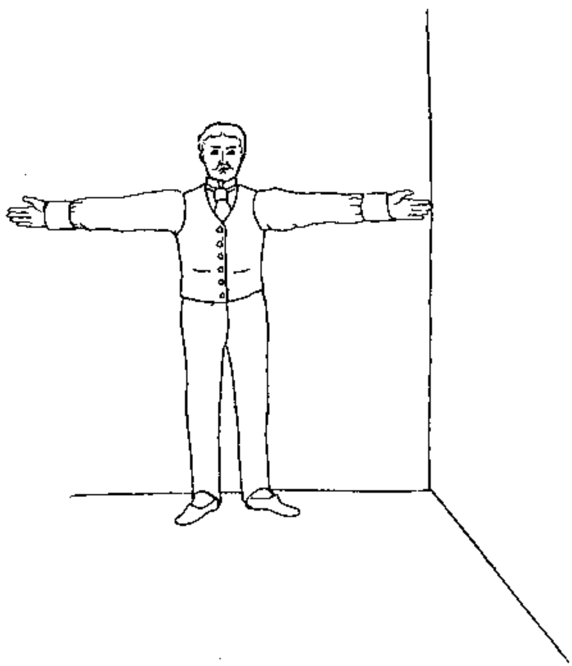
....

or from the above-named Professor.

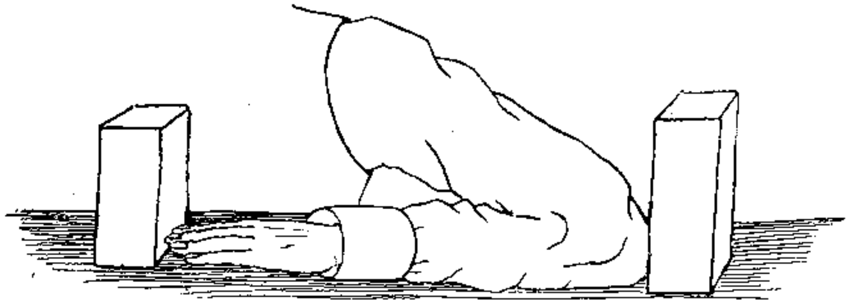
The measurements required in the case of each individual are to be to the nearest quarter of an inch, and to consist of the following:—

(I.) *Height.*—This measurement should be taken, if possible, with the person in stockings, if she or he is in boots it should be noted. The height is most easily measured by pressing a book with its pages in a *vertical plane* on the top of the head while the individual stands against a wall.

(II.) *Span of Arms.*—Greatest possible distance between the tip of one middle finger and the tip of the other middle finger, the individual standing upright against a wall with the feet well apart and the arms outstretched,—if possible with one finger against a doorpost or corner of the room.



(III.) *The Length of LEFT Forearm.* The arm being bent *as much as possible* is laid upon a table, with the hand flattened and pressed firmly against the table, a box, book, or other hard object is placed on its edge so as touch the bony projection of the elbow, another so as to touch the tip of the middle finger. Care must be taken that the books are both perpendicular to the edge of the table. The distance between the books is measured with a tape.



Or,

The arm being bent *as much as possible* the elbow is pressed against the corner of a room or the doorpost, the hand being flattened and pressed against the wall. The greatest distance from the tip of the middle finger to the corner or doorpost is to be measured.

Sample of filled in Data Card of Family Measurements.

		Height*		Span of Arms		Left Forearm	
One Family only		Feet	Inches	Feet	Inches	Feet	Inches
Father... ... ... (Not step-father)		5	9¼	6	1½	1	7¼
Mother ... ... (Not step-mother)		5	0¾	5	2	1	4¼
	Age						
Son ...	26	5	7¼	5	11	1	6½
Son ...	—	—	—	—	—	—	—
Daughter	30	5	4¼	5	5	1	4½
Daughter	24	5	5¼	5	6¼	1	5

Name and Address of Recorder (not to be published in any way, but for convenience of reference).

Miss A. L. Robinson,

Blounts Court Mansions, Kensington, S.W.

Both father and mother are absolutely necessary and should not be over 65 years of age.

All the measures are to be recorded to the nearest quarter of an inch. Before measuring read the notice circulated with this card, and kindly return the card as soon as possible to

[Name of individual collector was here inserted]

or to Professor Karl Pearson, University College, London, W.C.

* Put B against numbers if measure is taken in boots. If any person measured has ever broken a leg, arm or collar-bone, put L, A, C against all his or her measurements.

It is not for a moment suggested that the instructions or schedule form are ideal; they are of course open to criticism of a variety of kinds. But they were not settled without considerable thought and a definite reason for each point stated. Thus full growth is not reached at 18 years of age, perhaps not till 25. The growth, however, from 18 to 25 is relatively small, although sensible, and by fixing our limit at 25, we found a very large number of families would be cut off, for both parents would not be surviving, or, if surviving, beyond the age limit fixed for parents. Further, we should have been unable to interest college students effectively in the matter, as the bulk of them fall between 19 and 22. Again, it would have been better to take a lower maximum age for the parents, but in doing so we should again have greatly limited our available material. Better organs might undoubtedly have been selected than stature, span and forearm, e.g. head and finger measurements, but in such cases instruments and greater elaboration are needed, and the difficulty of obtaining upwards of 1000 families, already very great, would have been much intensified. We chose organs easily measured with moderate accuracy and asking for the nearest quarter-inch, only tabulated stature and span to the nearest inch, and forearm to the nearest half-inch. Thus the slight diurnal variations and the errors of measurement of the characters will not sensibly affect the constants calculated from our tables. Only a small percentage were measured in boots; we could not insist that ladies and gentlemen in middle life must remove their boots, or we might have met with a far larger number of refusals to be measured. Still the bulk of the measured did remove boots. After some experimenting on the effect of heels on apparent stature it was found that the subtraction of an inch from the recorded stature fairly represented the average increment due to boots. Hence the small percentage of boot entries was reduced before tabling by one inch.

Of course each family card did not provide us with four children, our maximum number allowed. Thus the number of our parental pairs lies for the different tables between 1000 and 1400, while for the fraternal correlations we have results based on 350 to 1400 pairs, according to the nature of the table. This is due to the fact that it was found far more difficult to get the measurements on *two* adult brothers, than on two sisters*. It was partly this defect in the number of pairs of brothers which led to the wider system of school measurements on brothers. The latter, however, do not modify but only confirm the results obtained from the smaller series in the *Family Records*.

I now propose to deal at length with the results obtained from our material.

(iii) *Theory applied.*

The regression in all cases is essentially linear, i.e. very closely linear within the limits of random sampling. It is impossible to give diagrams of all the 2×78

* Probably two adult brothers were far more rarely found both living at home, or if at home declined to be submitted to a measurement, which offered no immediate advantage to themselves.

regression lines of the 78 correlation tables, but the following three cases are a fair *random* sample of what actually occurs*.

Diagram I. *Stature of Father and Son.*

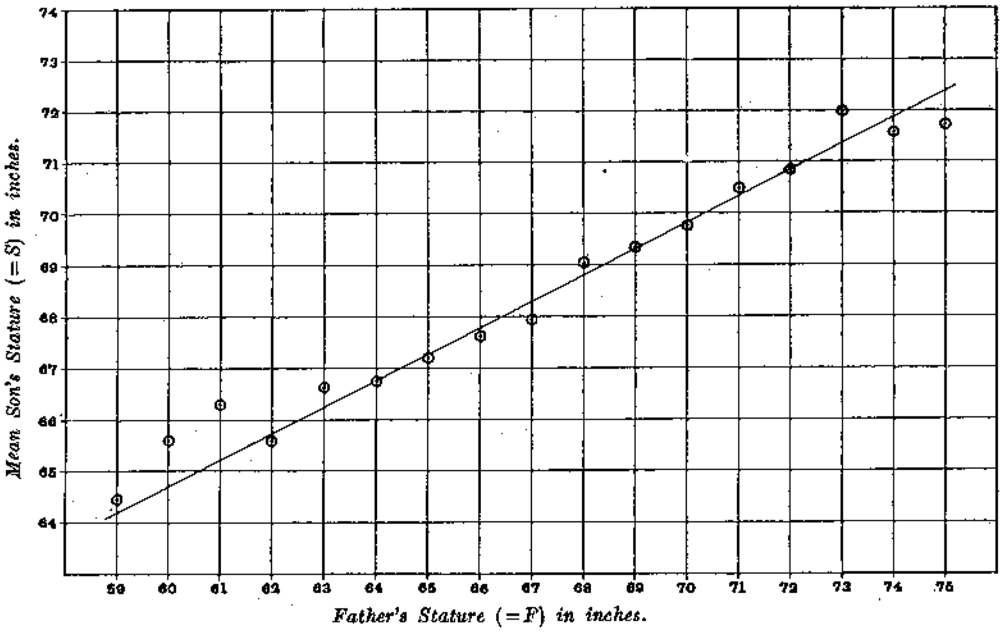
Diagram II. *Span in Mother and Daughter.*

Diagram III. *Brother's Forearm and Sister's Span,*

the latter being an example of a cross-correlation.

DIAGRAM I. *Probable Stature of Son for given Father's Stature.*

Regression Line: $S = 33{\cdot}73 + {\cdot}516\,F$. 1078 Cases.



It will be seen from these cases that, except near the terminals, where the numbers of cases are very few, that the regression is closely linear. We are thus relieved from any difficulties about regression or correlation. We have only to find the ordinary coefficient of correlation r, and the regression coefficient $r\sigma_1/\sigma_2$, and these will suffice to describe the average degree of hereditary resemblance. All this is done without any assumption of the normal curve of frequency. As a matter of fact, however, the normal curve very closely suffices to describe the distribution of many physical characters in a human population. This is illustrated in the accompanying diagrams which are fair samples of stature and span frequencies. In Diagram IV. we have the following data for stature in mothers, plotting frequency observed against theoretical frequency.

* A further case from the data, that of cubit in Father and Son, was given in *Biometrika*, Vol. II. p. 216.

DIAGRAM II. *Probable Span of Daughter for given Mother's Span.*
Regression Line: $D = 34{\cdot}18 + {\cdot}473\,M$. 1370 Cases.

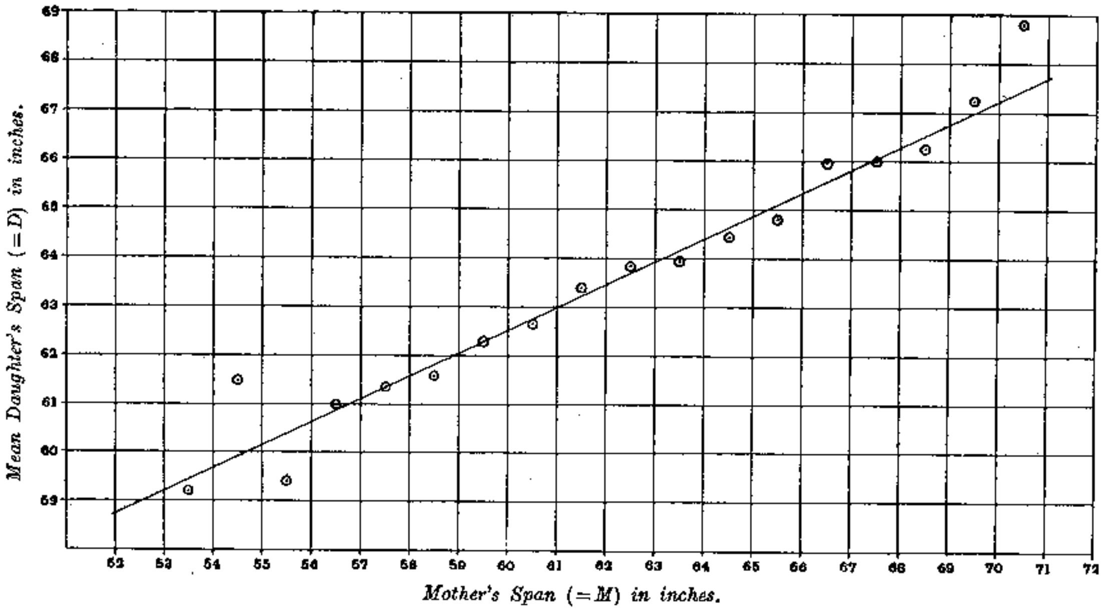


DIAGRAM III. *Probable Span of Sister for given Forearm in Brother.*
Regression Line: $S = 39{\cdot}66 + 1{\cdot}280\,B$. 1399 Cases.

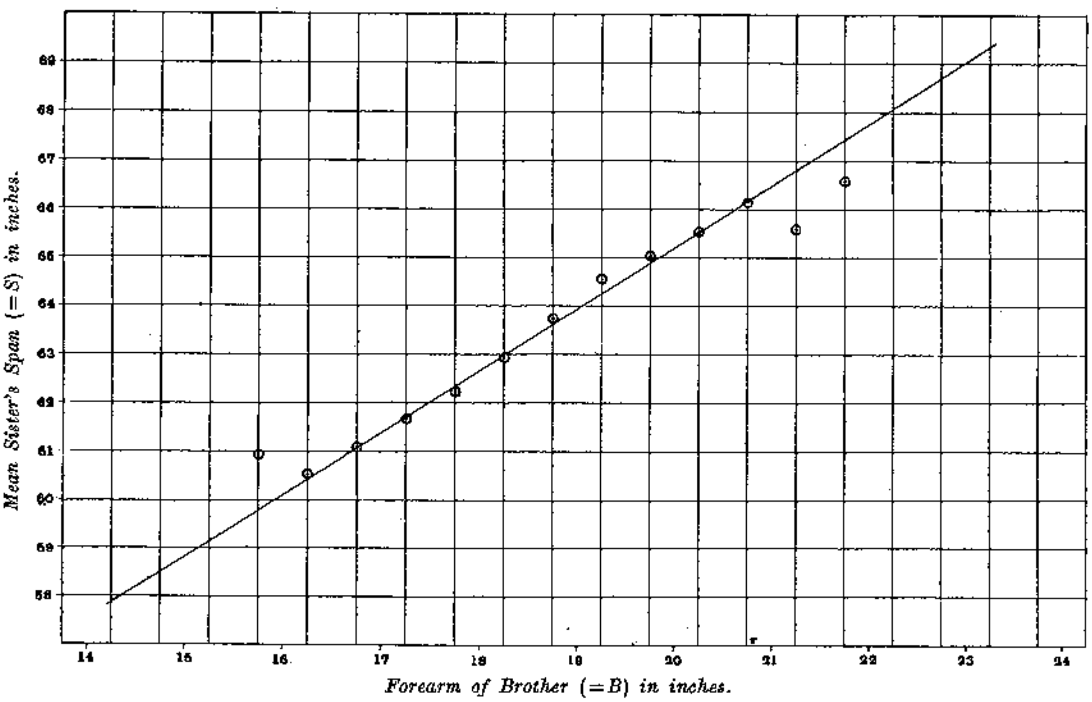
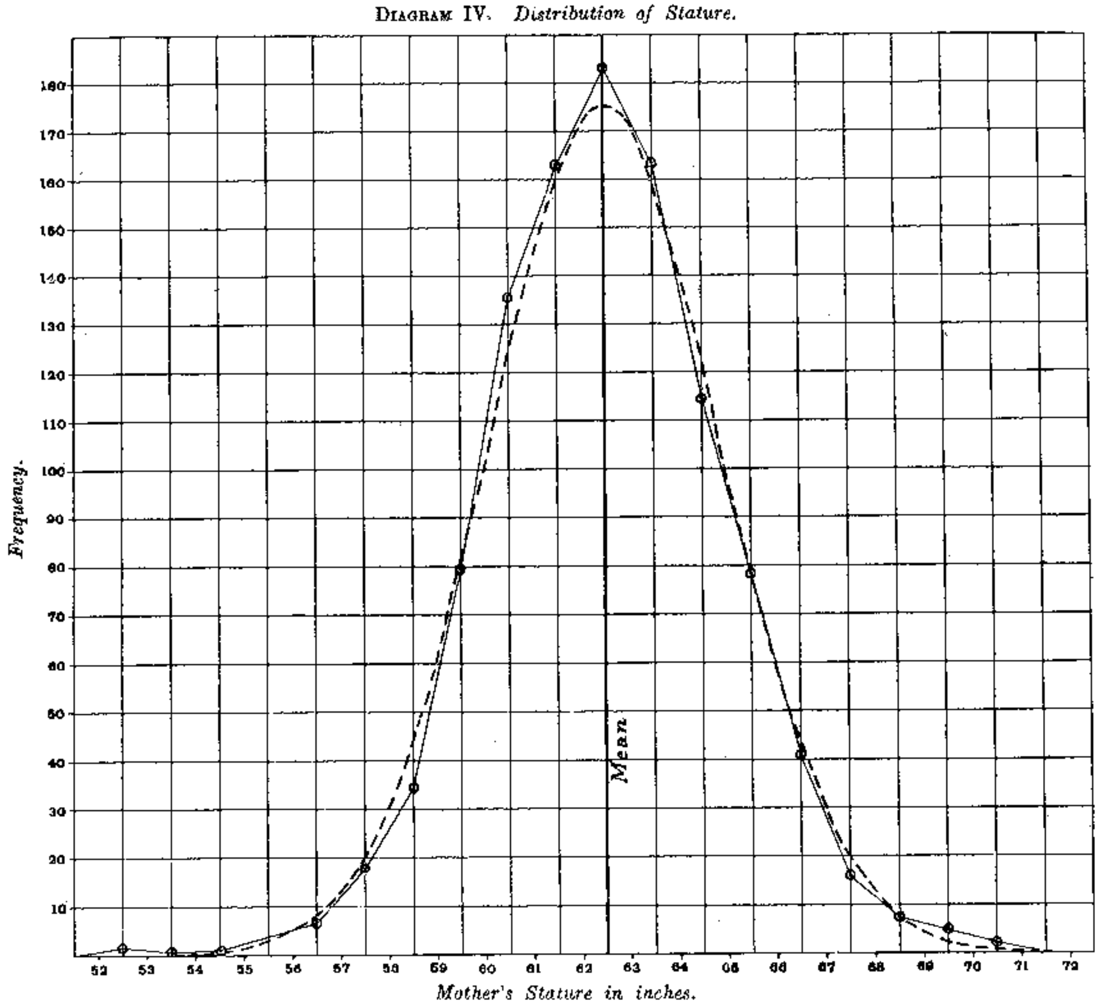


Diagram IV. *Distribution of Stature.*



Stature in Mothers. 1052 *Cases.* *Mean* $= 62''\cdot484$, *Standard Deviation* $= 2''\cdot3904$.

Stature in inches	52—53	53—54	54—55	55—56	56—57	57—58	58—59	59—60	60—61	61—62	62—63	63—64	64—65	65—66	66—67	67—68	68—69	69—70	70—71
Observed Frequency	1·5	·5	1	2	6·5	18	34·5	79·5	135·5	163	183	163	114·5	78·5	41	16	7·5	4·5	2
Normal Frequency	·9			2·6	7·9	20·9	44·5	80·8	124·1	160·3	174·3	159·4	122·8	79·5	43·2	20·1	7·7	2·5	·8

Sheppard's Tables* were used. If we test goodness of fit by my general method†, using Elderton's Tables and notation‡, we find: $\chi^2 = 14\cdot47$, and for

* *Biometrika*, Vol. II. p. 182 *et seq.* † *Phil. Mag.* Vol. I. pp. 157—175.

‡ *Biometrika*, Vol. I. p. 155 *et seq.*

17 groups this gives $P = \cdot 56$, or, if stature in mothers really obeys a normal law, we should expect worse results by way of fit in 56 out of 100 samples of 1052 mothers. Thus the degree of fit may be considered good. There is some irregularity at the left-hand tail, where I have clubbed three groups together. There is generally an improbable outlier or two in most of these distributions, possibly the result of some slip in measurement, or perhaps special deformity or result of disease not recorded on the cards*.

In Diagram V. we have the following data for span in sons:

Span in Sons. 1156 *Cases.* *Mean* $= 69''\cdot 94$, *Standard Deviation* $= 3''\cdot 0869$.

Span in inches	58—59	59—60	60—61	61—62	62—63	63—64	64—65	65—66	66—67	67—68	68—69	69—70
Observed Frequency	·5	·5	·5	3·5	4	13	32	64·5	84·5	105	132·5	153·5
Normal Frequency	2·2			3·7	8·3	17·2	31·9	53·4	80·5	109·1	133·2	147·3

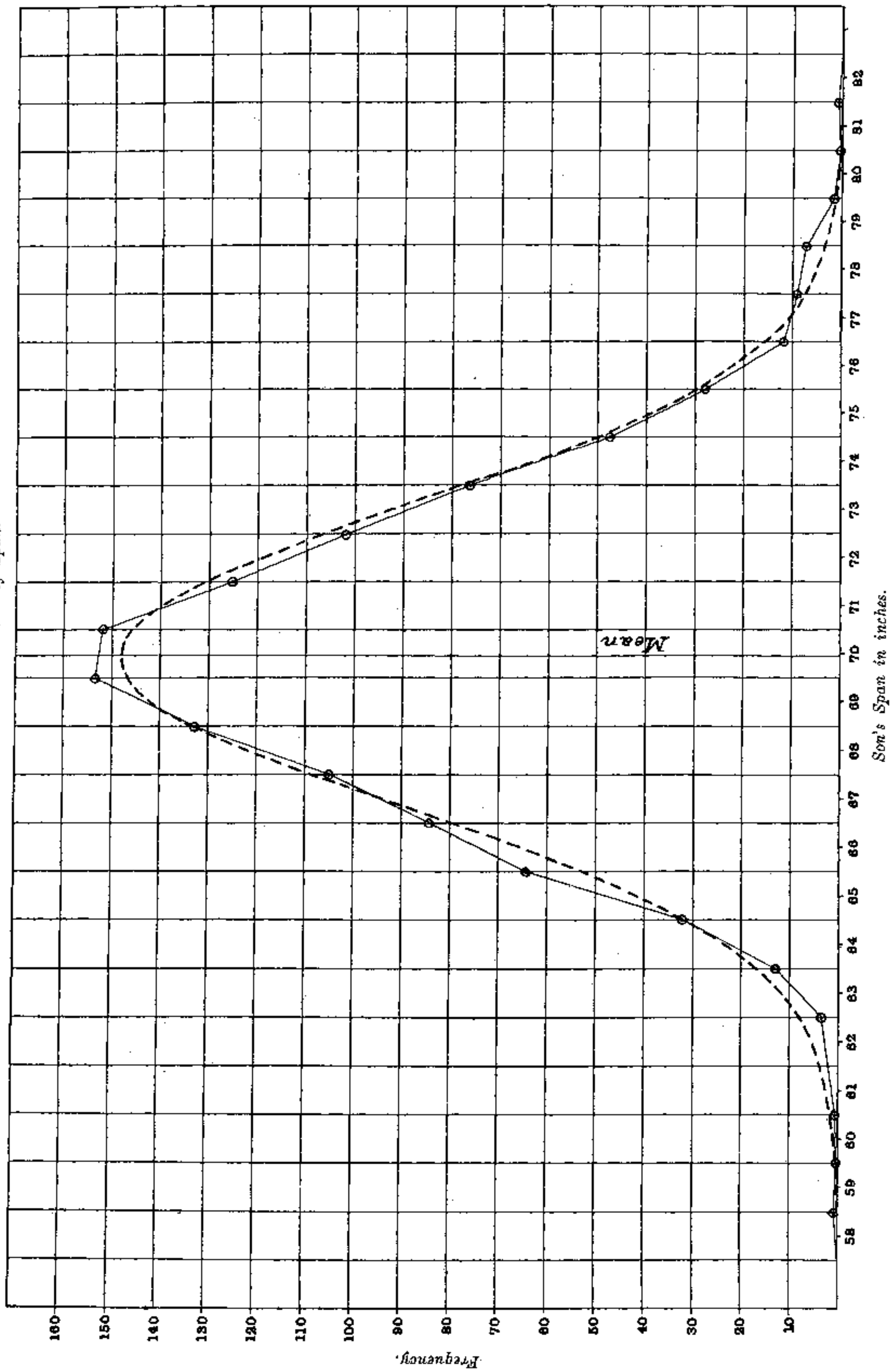
Span in inches	70—71	71—72	72—73	73—74	74—75	75—76	76—77	77—78	78—79	79—80	80—81	81—82
Observed Frequency	152	125·5	102	76·5	47·5	28	11·5	9	7	1·5	·5	1
Normal Frequency	146·3	131·1	105·9	76·9	50·6	29·8	15·8	7·6	3·2	1·3	·6	

In this case we have for 21 groups, $\chi^2 = 14\cdot 63$ and $P = \cdot 80$, or in 80 trials out of 100 we should expect the group of 1156 sons to diverge more from the normal distribution than our observed results do. Again we have an excellent fit. It would seem that for stature and span we may fairly use a normal distribution, even as it may be used for cranial and cephalic measurements†. But biometric results are always a field for surprises, partly because of the complexity of causes to be dealt with, partly because we are really only at the beginning of our

* It is even conceivable that a measurer went out of the way to get a very small man or woman, as in a case where one contributor wrote: "I have got with some difficulty the ——'s, a very tall family."

† Macdonell, *Biometrika*, Vol. I. p. 183 *et seq.* and Fawcett, *Ibid.* Vol. I. p. 443.

DIAGRAM V. *Distribution of Span.*



collections of data. I may have been unfortunate in my choice of the forearm as more difficult of measurement, or more subject than span to growth influences, but the results for the forearm diverge considerably more from normality than those for stature or span. I give my conclusions for the three cases I have investigated. These are as follows:

Forearm in Fathers: 14 groups, $\chi^2 = 35{\cdot}18$, $P = {\cdot}000$,
„ in Daughters: 14 groups, $\chi^2 = 33{\cdot}51$, $P = {\cdot}003$,
„ in Sons: 15 groups, $\chi^2 = 30{\cdot}76$, $P = {\cdot}007$.

The improbability of the normal distribution is, however, in all these cases chiefly due to a little lump of "outliers" at the "giant" end of the distribution. There are four fathers with excessive forearms, four daughters with the like and four sons also. These twelve cases cannot, I feel sure, be in the bulk due to slips of measurement, they may be due to some anomalous growth or to a reversion to an excessive radius. If we remove them we find roughly: $P = {\cdot}45$ for fathers, $= {\cdot}21$ for sons and $= {\cdot}18$ for daughters, i.e. we obtain an excellent normal curve fit in the first case, and quite fair ones in the other two. We are therefore forced to the conclusion that forearm in the bulk follows fairly closely a normal distribution, but there appears to exist in man a small abnormal group with excessive forearms, of less than ·5 per cent. The following is the table of observed and theoretical results for forearm in fathers:

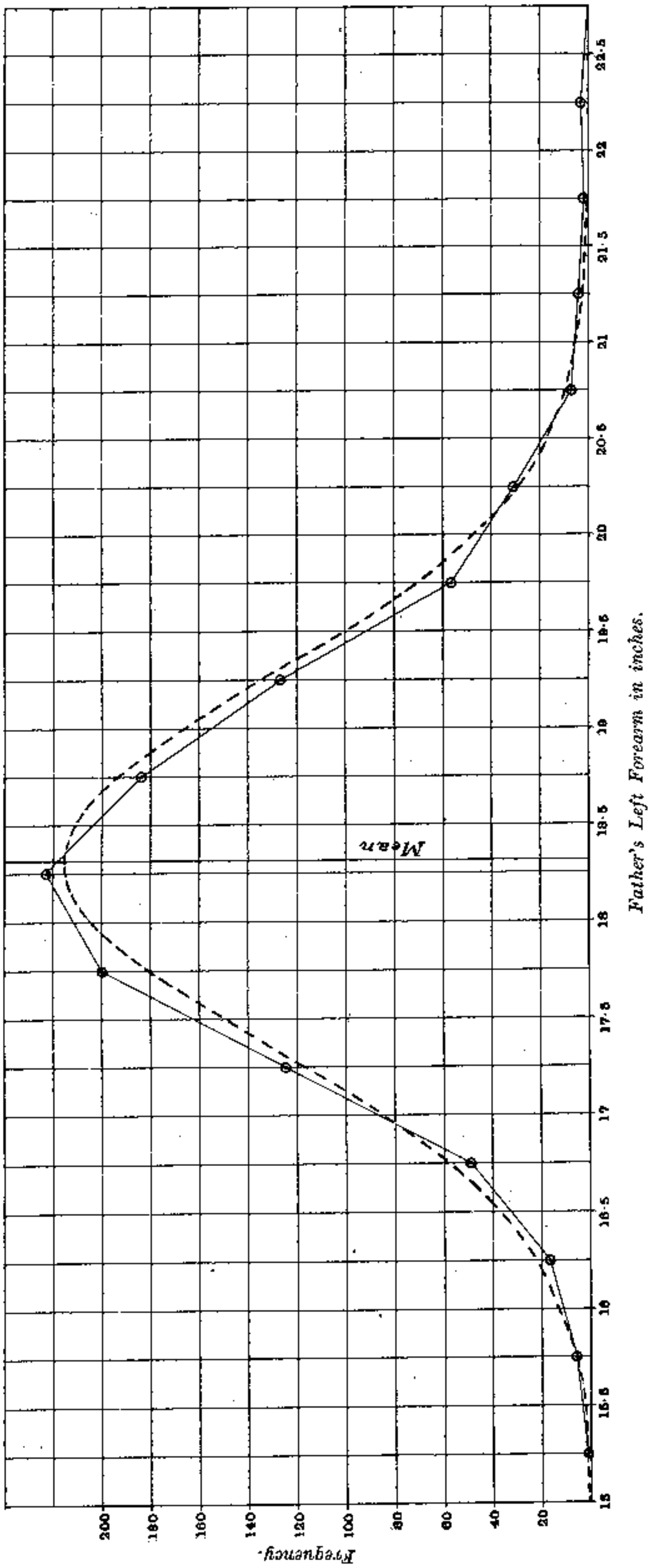
Forearm in Fathers. 1050 *Cases.* *Mean* = 18″·31, *Standard Deviation* =″·963.

Forearm in inches	*15—15·5*	*15·5—16*	*16—16·5*	*16·5—17*	*17—17·5*	*17·5—18*	*18—18·5*	*18·5—19*	*19—19·5*	*19·5—20*	*20—20·5*	*20·5—21*	*21—21·5*	*21·5—22*	*22—22·5*
Observed Frequency	1	6·5	17	49	125·5	200	235·5	183·5	127	57·5	31·5	8	3·5	2	2·5
Normal Frequency	1·9	6·7	23·0	59·6	119·0	182·2	214·8	194·3	135·0	72·0	29·5	9·3	2·2	·5	

This is shown in Diagram VI. The mere graphical inspection of such a result as this would hardly lead us to give proper weight to the abnormal group of outliers, which carry P from ·45 to ·000. To some it might seem a good fit, but the trained eye sees at once defects and $P = {\cdot}000$ shows how great they are*.

* It is almost in vain that one enters a protest against the mere graphical representation of goodness of fit, now that we have an exact measure of it. As typical cases in which quite recently arguments are based on mere graphical appreciation, I would refer to an article by Thorndyke on "Fertility in Man" (*Popular Science Monthly*, Vol. 63, pp. 64 and 84) wherein the skewness of fertility distributions is denied on graphical appreciation of curves, which are analytically skew by odds of the order of a 1000 to 1! Another transgressor is Johannsen, who in his recent work *Ueber Erblichkeit in Populationen und in reinen Linien*, asserts on mere graphical appreciation that certain data are normal and other non-normal and bases arguments on these assertions, whereas the eye alone cannot possibly judge whether or no his distributions follow the normal law. If biologists use biometric methods, they must be reminded that no vague appreciation will answer biometric problems, they must study sufficient mathematics to apply the necessary tests and criteria on which alone biometric arguments can be safely based.

DIAGRAM VI. *Distribution of Forearm.*



The following is the Table for forearm in sons.

Forearm in Sons. 1156 *Cases.* *Mean* = 18″·52, *Standard Deviation* = ″·983.

Forearm in inches	14—14·5	14·5—15	15—15·5	15·5—16	16—16·5	16·5—17	17—17·5	17·5—18	18—18·5	18·5—19	19—19·5	19·5—20	20—20·5	20·5—21	21—21·5	21·5—22	22—22·5	22·5—23
Observed Frequency	1	1	1	5·5	10	39·5	95	177·5	260·5	225	166·5	105	41	14·5	7·5	4·5	—	—
Normal Frequency	·2		1·0	4·7	17·1	47·5	102·7	171·7	223·8	225·7	177·3	107·7	51·0	18·7	5·3	1·2	·2	

This Table as well as the previous one suggests that a small but sensible element of skewness in the forearm as well as the outlying group contributes to the divergence from normality.

It will be seen that our present data justifies Mr Galton's original use for stature of the normal curve and the normal surface, i.e.

$$z = \frac{N}{2\pi\sigma_x\sigma_y\sqrt{1-r^2}} e^{-\frac{1}{2}\frac{1}{1-r^2}\left\{\frac{x^2}{\sigma_x^2} - \frac{2xyr}{\sigma_x\sigma_y} + \frac{y^2}{\sigma_y^2}\right\}}$$

(where $z\,\delta x\,\delta y$ is the frequency of a group of relative pairs having characters with deviations from their means lying between x, y and $x+\delta x$, $y+\delta y$; N being the total number of pairs, σ_x, σ_y being the standard deviations, and r the coefficient of correlation of the two characters: see *Phil. Trans.* Vol. 187, A, p. 264 *et seq.*). It also is fully justified for span and even for forearm (if we remember that there exists a small group of "outliers"). The normality of the distribution adds little, however, to our investigation, as long as we can show that the regression is practically linear (see Diagram III.). The practical value of normality arises chiefly when we pass from measurable characters in man to those that are not capable of exact quantitative measurement, for here every exception to normality weakens our general position.

The general linearity of our regression lines enables us in the present case to apply a simple theory, as soon as we have calculated the means, the standard deviations, and the correlations of the various characters.

These will enable us, by using the formulae of simple or multiple correlation, which depend simply on linearity, to predict the probable character in any individual from a knowledge of one or more parents or brethren ("siblings," = brothers or sisters). But without further assumption they do not enable us to test the effect of long-continued selection in establishing stocks; for we have no ancestral correlations, beyond the parental, for the characters dealt with. Ancestral correlations beyond the parental are, however, known for man in eye-colour inheritance (up to great-grandparents), for horses in coat-colour (up to great-great grandparents), and for dogs in coat-colour (up to grandparents). Hence, if the parental correlations for men, horses and dogs are sensibly the same, we shall have small hesitation in assuming that the ancestral correlations for stature, span and forearm in man are closely alike in value to those for his eye-colour and for other characters in horse or dog. We shall thus be able to extend our theory, so as to deduce from our data the rate at which selection, natural or artificial, would establish stocks in man, and further, the limitations there are to the conception of an indefinitely active regression following on the suspension of selection.

It will be found that as far as the actual values are concerned our *Family Records* give values for heredity in man very sensibly larger than Mr Galton's stature data, and much closer to those obtained from his eye-colour data and for coat-colour in horses and dogs.

(iv) *Size and Variability of Characters in the two Generations.*

I will first consider whether there is a sensible change in type between the older and younger generation of our own epoch. The problem is not so easy to answer as it might *à priori* appear to some. We have the following results:

TABLE I. *Alteration in Type.*

Means		Stature	Span*	Forearm
1st Generation	Father ...	67″·68 ± ·06	68″·67 ± ·07	18″·31 ± ·02
	Mother ...	62″·48 ± ·05	61″·80 ± ·06	16″·51 ± ·02
2nd Generation	Son	68″·65 ± ·05	69″·94 ± ·06	18″·52 ± ·02
	Daughter...	63″·87 ± ·05	63″·40 ± ·05	16″·75 ± ·02
Standard Deviations		**Stature**	**Span**	**Forearm**
1st Generation	Father ...	2″·70 ± ·04	3″·14 ± ·05	0″·96 ± ·01
	Mother ...	2″·39 ± ·04	2″·81 ± ·04	0″·86 ± ·01
2nd Generation	Son	2″·71 ± ·04	3″·11 ± ·04	0″·98 ± ·01
	Daughter...	2″·61 ± ·03	2″·94 ± ·04	0″·91 ± ·01
Coefficients of Variation		**Stature**	**Span**	**Forearm**
1st Generation	Father ...	3″·99 ± ·06	4″·64 ± ·07	5″·24 ± ·08
	Mother ...	3″·83 ± ·06	4″·62 ± ·07	5″·21 ± ·08
2nd Generation	Son	3″·95 ± ·06	4″·51 ± ·06	5″·29 ± ·07
	Daughter...	4″·09 ± ·05	4″·71 ± ·06	5″·43 ± ·07
Organic Correlations		**Stature and Span**	**Span and Forearm**	**Forearm and Stature**
1st Generation	Father ...	·783 ± ·008	·752 ± ·009	·640 ± ·012
	Mother ...	·756 ± ·009	·677 ± ·011	·597 ± ·013
2nd Generation	Son	·802 ± ·007	·758 ± ·008	·686 ± ·011
	Daughter...	·828 ± ·006	·771 ± ·007	·716 ± ·009

* We note here a secondary sexual difference, the span on the average is about 1″ greater than the stature in man, and about ·5″ less than the stature in woman.

Now this Table contains a number of most interesting points.

In the first place the probable errors show us that for all three characters in both sexes the younger generation is distinctly larger than the older generation, son than father, daughter than mother. Is this a real progress in type? Taking Mr Powys' diagram for shrinkage in stature*, we should expect our men to reach a maximum at about 28 and our women at 25. Hence, since the average age of our younger generation is not more than 22 years, the younger generation cannot have reached its maximum. On the other hand, our average age of parents must be about 50. Let us suppose them to be 55 even. The difference in age of parents and offspring would thus mark a shrinkage of about ·5″ at a maximum. But the difference between fathers and sons is about an inch for stature and span, and for mothers and daughters about an inch and a half. It seems impossible therefore to attribute the whole change between the two generations to old-age shrinkage. In the next place, can it be due to periodic selection, i.e. only a portion of the younger generation become fathers and mothers? If so, we should expect not only a change in type, but a change in variability between the two generations. Comparing the standard deviations of fathers and sons, we see that fathers and sons are within the limits of random sampling equally variable. On the other hand daughters' standard deviations are in every case sensibly larger than those of their mothers. It would thus seem highly probable that the causes at work in the cases of the two sexes are not entirely the same. Mothers of adult children are a more stringently selected portion of the population than fathers appear to be. Of course some change in type between mothers and adult daughters is undoubtedly due to the fact of child-bearing, independent of any selection in childbed. But it is difficult to see how a physiological effect of this kind could change variability as well as type. I have shown that there is a slight correlation between size and fertility in women†, and this may be partially the source of the observed effect. Whether, however, the result be due to natural or reproductive selection, the change in the variability of the two generations of women seems to me to indicate that there is a selective change going on in the women of the middle classes in this country. The difference in type between fathers and sons,—since there is no change of variability,—might be more likely to be due to improved physical exercise. Of course a portion of the change in the women must also be attributed to this, but the change in variability forbids, I think, its being entirely attributed to this source.

However we judge the matter, whether we consider it due to selection, or to better environment, nourishment, or exercise, there seems no reason to suppose that the population, as far as the middle classes are concerned, is degenerating. In span, stature and forearm the younger generation is sensibly better than its parents.

* *Biometrika*, Vol. I. p. 47.

† *R. S. Proc.* Vol. 59, p. 303. See also Vol. 66, p. 28 *et seq.*

If we compare the two sexes, we see that except in the matter of stature the married woman is *relatively* as variable as the married man, while in all three characters the young woman is relatively more variable than the young man. The supposed preponderance of male variability is thus again very fully negatived, for large statistics of typical physical characters in mankind*.

Turning to the correlations we see (*a*) that in the older generation the mother is less highly correlated than the father, (*b*) that in the younger generation the son is less highly correlated than the daughter, (*c*) that the younger generation of both sexes is more highly correlated than the older generation. Now the effect of selection is to reduce correlation, hence if selection—a selective death-rate—be a real factor in the case of man and we know it to be so, we should certainly expect the correlations between the ages of youth and of middle life to be reduced. They are thus reduced, but far more markedly so in the case of woman than in that of man. Now as far as our data at present reach we know that the male baby is more variable and more highly correlated than the female†. In youth the woman is more variable and more highly correlated than the man; in adult age after child-bearing she is less highly correlated and perhaps very slightly less variable. It would thus seem that between birth and manhood the male is selected and falls in both variability and correlation below his sister. With womanhood comes her period of selection, sexual selection for wifehood, natural and reproductive selection for motherhood. These act with a little expected intensity and leave mothers of adult families with far less variability and correlation than their husbands have.

Of course these changes in variability and correlation may be partly growth changes, but since on the average the man reaches his maximum size four or five years later than the woman and at least four or five years beyond the average age of our group sons, it is difficult to account for the wide difference in variation and correlation between daughters and mothers as compared with that between sons and fathers by growth changes only.

I am inclined to think Table I. is very illustrative of the nature of selection among mankind, and further that it is also hopeful, not as regards the quantity, of which it takes no account, but as regards the quality of the offspring of a fair sample of the English middle classes.

(v) *Direct Assortative Mating in Man.*

We have seen above that all women, if they indeed become wives, do not become the mothers of adult children, i.e. the mothers of the second generation are not a random sample of their own generation. However it may arise there is

* See *The Chances of Death*, Vol. I. pp. 256—377. A recent criticism by Mr Havelock Ellis of my view that there is no preponderating variability of man over woman seems to need no reply, for the author does not appear to understand what weight is to be given to scientific evidence as compared with vague generalities.

† *R. S. Proc.* Vol. 66, p. 25.