"Data for the Problem of Evolution in Man. V. On the Correlation between Duration of Life and the Number of Offspring." By Miss M. BEETON, G. U. YULE, and KARL PEARSON, F.R.S., University College, London. Received April 19,—Read June 14, 1900.

1. According to the Darwinian theory of evolution the members of a community less fitted to their environment are removed by death. But this process of natural selection would not permanently modify a race, if the members thus removed were able before death to propagate their species in average numbers. It then becomes an important question to ascertain how far duration of life is related to fertility. In the case of many insects death can interfere only with their single chance of offspring; they live or not for their one breeding season only.* A similar statement holds good with regard to annual and biennial plants. In such cases there might still be a correlation between duration of life and fertility, but it would be of the indirect character, which we actually find in the case of men and women living beyond sixty years of age—a long life means better physique, and better physique increased fertility. On the other hand, there is a direct correlation of fertility and duration of life in the case of those animals which generally survive a number of breeding seasons, and it is this correlation which we had at first in view when investigating the influence of duration of life on fertility in man. The discovery of the indirect factor in the correlation referred to above was therefore a point of much interest. For it seems to show that the physique fittest to survive is really the physique which is in itself (and independently of the duration of life) most fecund.

In continuing our study of the inheritance of longevity,† it occurred to us that it would be possible at the same time as extracting data for duration of life to extract data bearing on the size of the family. Accordingly Miss M. Beeton, in working upon family histories, made records of this additional character. Meanwhile Mr. G. U. Yule, who had been independently at work on this very point, drew my attention again to the matter in connection with a passage in the 'Grammar of Science.'‡ We agreed to unite our material, and the result is the following joint paper.§

* Of course longer life may denote greater chance of male or female meeting female or male, but in this case we have not a *graduated* fertility, the individual is or is not once fertile.

† 'Roy. Soc. Proc.,' vol. 65, p. 290.

‡ Second edition, p. 445.

§ We have also to very heartily thank Mr. L. N. Filon, M.A., and Mr. K. Tressler for aid in the calculations and in the preparation of diagrams.

2. The data dealt with in this paper consist of four series, the first three collected and reduced by Miss M. Beeton, and the fourth series by Mr. G. U. Yule. The sources from which they were extracted are the following :—

Mothers.   Length of Life and Size of Family.

Series I.—Taken from the 'Whitney Family, of Connecticut,' a well-known history of an American Quaker family. In order to complete a thousand and more entries some very few additions were made from the 'Backhouse Family,' the history of an English north-country Quaker family. This series may be taken to substantially represent American women more or less closely connected with one strain of blood, either by inheritance or by marriage.

As soon as these results were tabled it was noticed that the average age at death of mothers was immensely below the average age at death of Englishwomen. Further, the maximum frequency of deaths which occurs at 35 to 40 was actually greater than the maximum which occurs between 70 to 75 ! Either then American women of this class die very early, or the women of the Whitney family suffer under some hereditary taint, *e.g.*, phthisis.

Series II.—Taken from purely English Quaker records. The data for this series were drawn from a great variety of histories and records most kindly placed at our disposal by Mr. Isaac Sharp, Secretary of the Society of Friends, and by the Secretary of the well-known insurance office, the Friends' Provident Association, both of whom we desire to cordially thank for their aid. The object here was to avoid the selection which may unconsciously be made when the data are drawn from the records of a single family.* In these two series, as in the third series, we selected the records of the Society of Friends because—

(*a.*) They appear to be the most trustworthy and complete of the family histories available.

(*b.*) The ages at death of the women are given ; these are rarely recorded in other genealogical works.

(*c.*) The artificial limitation of fertility seems to be less probable in a strongly religious community like the Friends than in other classes of the population.

In this series the mean age at death, the modal age, and other constants are quite fairly in accord with what we know of the population at large.

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* Of course a "family" history like that of the Whitney family, professing to deal with all the descendants of a single pair, really contains an immense addition through marriage of other strains.

Fathers. Length of Life and Size of Family.

Series III.—The great bulk of the data was extracted from the American Whitney Family. Here the features noted for the women were again observed in the men, but to a much less marked degree. There was a rather high maximum frequency of death at 45,* but not so high as the maximum at 75, and the average age at death was somewhat lower than we find for the general English population. On the whole the series is a very good one.

Series IV.—Extracted from Burke's 'Landed Gentry.' It has been stated elsewhere† that this is a good class for such data. It possesses a higher average fertility than the Peerage, and is a class in which there is probably comparatively little artificial restriction. Unfortunately it offers no material for the age at death of women.

3. The following are the chief results obtained from the reduction of these series :—

I.—Table of General Results.

Series.	Parent.	Mean age at death.	Mean size of family.	S.D. Age at death.	S.D. Size of family.	Correlation fertility and duration of life.	Regression. Whole table.	Regression. Life 50 years and under.	Regression. Life 50 years and over.
I	Mother	53·292	5·269	4·091	3·409	0·5000	0·4174	0·8085	0·2237
II	Mother	61·183	5·811	3·769	3·479	0·2374	0·2191	0·7029	0·0941
III	Father	58·086	5·469	3·213	3·453	0·4926	0·5282	0·8414	0·2186
IV	Father	63·577	5·336	3·037	3·387	0·2010	0·2240	0·5940	0·0720

In this table the unit for the standard deviation of the age at death is 5 years, the unit of the grouping in the accompanying tables. Thus age at death of mothers 35 gives the frequency of all the group of mothers dying between 32·5 and 37·5. Of course the age at death of certain parents would lie exactly on the boundary of a group, but such exact information is very rarely forthcoming, and when it is in a few cases forthcoming, *i.e.*, the day of both birth and death is given, it is very improbable that the age of death exactly bisects the year. Thus no fractionising was found necessary in the first three tables. In the 'Landed Gentry,' owing to the nature of the record, Mr. Yule found a small amount of fractionising necessary, and this appears in the table for Series IV. In the regression coefficients above tabulated 5 years is again the unit, and the coefficient of regression is the constant by which

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* The existence of a modal value about 45 has been already noted in the resolution of the mortality curve; it is the mode of the middle age mortality component. See 'Phil. Trans.,' A, vol. 186, p. 408, and Plate 16.

† 'Phil. Trans.,' A, vol. 192, p. 257.

the deviation in the age at death from the mean age at death, measured in 5-year units, must be multiplied in order to obtain the probable deviation of the family from the mean family.

II.—Table of Regression Formulæ or Curves.

y = Size of Family, x = Duration of Life.

Series I. American Mothers.

(a) For all lives. Straight line :
$$y = 0{\cdot}8211 + 0{\cdot}083{,}472x$$
(b) For lives of 50 years and under. Straight line :
$$y = -1{\cdot}9881 + 0{\cdot}163{,}233x$$
(c) For lives of 50 years and over. Straight line :
$$y = 3{\cdot}5531 + 0{\cdot}044{,}748x$$

Origin of x at birth and unit of x one year.

(d) For all lives. Cubical parabola. Origin of x at 55 years and unit = 5 years :

$$y = 6{\cdot}0208 + 0{\cdot}328{,}474x - 0{\cdot}035{,}056x^2 + 0{\cdot}003{,}000x^3$$

Series II. English Mothers.

(a) For all lives. Straight line :
$$y = 3{\cdot}1781 + 0{\cdot}043{,}819x$$
(b) For lives of 50 years and under. Straight line :
$$y = -0{\cdot}6222 + 0{\cdot}140{,}584x$$
(c) For lives of 50 years and over. Straight line :
$$y = 4{\cdot}9341 + 0{\cdot}018{,}810x$$

Origin of x at birth and unit of x one year.

(d) For all lives. Cubical parabola. Origin of x at 57·5 years and unit = 5 years :

$$y = 6{\cdot}4092 + 0{\cdot}079{,}120x - 0{\cdot}052{,}719x^2 + 0{\cdot}005{,}717x^3.$$

Series III. American Fathers.

(a) For all lives. Straight line :
$$y = -0{\cdot}6819 + 0{\cdot}105{,}644x$$
(b) For lives of 50 years and under. Straight line :
$$y = -2{\cdot}6766 + 0{\cdot}168{,}277x$$
(c) For lives of 50 years and over. Straight line :
$$y = 3{\cdot}3976 + 0{\cdot}043{,}726x$$

Origin of x at birth and unit of x one year.

(d) For all lives. Cubical parabola. Origin of x at 55 years and unit = 5 years :

$$y = 5{\cdot}8187 + 0{\cdot}363{,}122x - 0{\cdot}047{,}438x^2 + 0{\cdot}003{,}035x^3.$$

Series IV. English Fathers.

(*a*) For all lives.   Straight line :

$$y = 2 \cdot 4877 + 0 \cdot 044,800x$$

(*b*) For lives of 50 years and under. Straight line :

$$y = -1 \cdot 0061 + 0 \cdot 118,800x$$

(*c*) For lives of 50 years and over. Straight line :

$$y = 4 \cdot 6717 + 0 \cdot 014,400x$$

Origin of x at birth and unit of x one year.

(*d*) For all lives.   Cubical parabola.   Origin of x at 60 years and unit = 5 years :

$$y = 5 \cdot 5075 + 0 \cdot 153,403x - 0 \cdot 041,940x^2 + 0 \cdot 003,636x^3.$$

The constants of the straight lines for all these series have been found at once by fitting the best straight line to the observations, *i.e.*, by using the regression formula—

$$y - \text{mean } y = \text{coefficient of regression} \left(\text{or } r \frac{\sigma_y}{\sigma_x} \right) \times (x - \text{mean } x).^*$$

The cubical parabolas have been fitted by the method of moments.†

The whole of this system of formulæ has been plotted, and is exhibited graphically in the accompanying diagrams (pp. 176—179). These diagrams suffice to give the entire graphical solution of this problem to an exactness sufficient for most practical purposes.   A careful examination of these diagrams will enable the reader to follow our general conclusions even more clearly than inspection of the algebraic formulæ.

4. *General Conclusions.*—(i.) The regression straight line for all lives, *aa*, does not give a satisfactory picture of the relation between age at death of a parent and the average number of offspring.   We see at once that it is too steep at the beginning and not steep enough at the end of life.   Accordingly, starting from 50 years as the sensible limit to woman's child-bearing period, the mothers were broken up into two groups, and the regression lines calculated separately for lives of 50 years and under, and for lives of 50 years and over.   In this way quite a reasonable fit was obtained to the observations.   For convenience, the age of 50 was also taken as a dividing age for fathers. In all four cases the regression line *cc* for parents living beyond 50 years shows a quite sensible deviation from the perpendicular, or *fertility is correlated with longevity even after the fecund period is passed.*

If we take American mothers there is no doubt of this increasing

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* See Yule, 'Roy. Soc. Proc.,' vol. 60, p. 477.

† I have shown in a memoir not yet published (*a*) how to fit all types of curves, but particularly parabolas of any order, by the method of moments; and (*b*) that such method gives results practically of the same order of exactness as those given by the method of least squares.—K. P.

fertility even up to 90 years of age. With English mothers it is less marked, but appears to be quite true up to 75 years. Beyond 75 there appears to be a slight decrease. Turning to the two series for fathers we see that we might possibly have better taken 60 than 50 as a dividing age, for the general trend of the observations is much the same up to 60 years. After this there is still a sensible trend in the American results, so that aged fathers are again the most fertile. With the English fathers this relation is, as in the case of English mothers, far less marked, although it is sensible if we take fathers above 50 years.

Thus I think we might sum up : That the peculiar physique in both men and women which leads to longevity is also associated with greater fecundity. Of two women who both live beyond 50 years, the longer lived is likely to have had before 50 the larger family. The association is, however, much greater for American than English parents, although the American parents dealt with are, in the great majority of cases, of Anglo-Saxon race. Climate, mode of life, generally selection and environment, seem to be differentiating in this respect the English and the Anglo-American. The English Friends, we should suppose, would be a class very comparable with the American Friends, yet their average life is longer, their fertility greater, and there is less association between longevity and fecundity. In both cases our algebraical formulæ show that American men and women are more alike, and English men and women are more alike than the women to the women or the men to the men of the two races. This is the more remarkable, as the English Friends as a class are by no means identical with the Landed Gentry.

(ii.) In order to represent the *continuous* change in the regression, which cannot be done by two straight lines, which only enable us to distinguish the fecund and non-fecund periods of life, the statistics were fitted with cubical parabolas. The regression line at any age in life may then be looked upon as the tangent to the cubical parabola at that age. An inspection of Diagrams 3, 4, 7, 8 shows what an excellent expression such parabolas are for these statistics.

For American mothers and fathers we see dy/dx consistently positive throughout life, and we have a most excellent graphical demonstration of the physical characters which tend to longevity being also associated with fecundity. In the English fathers the same feature appears in a much less marked degree ; there is a point of inflexion in the curve, although dy/dx remains positive. Up to about 75, however, the number of offspring continues to increase with duration of life, and when we break off at 95, the curve has got a renewed outward trend. With English mothers, however, the curve has a small but sensible trend inwards in old age. For fifteen years after the climacteric increased life connotes larger family, *i.e.*, shows fecundity associated

with the physique peculiar to longevity, but beyond 65, as judged by the parabola, longevity is slightly unfavourable to fecundity.*

The following are the values of the regression coefficients obtained by differentiating the cubical parabola and referring to birth as origin and a year as unit :—

Table III.—Regression Coefficients showing their Change with Duration of Life.

Series.	Old method, line *aa*.	Cubical parabola.
I	0·0835	$0·437,741 - 0·010,7240z + 0·000,0720z^2$
II	0·0438	$0·711,949 - 0·019,9955z + 0·000,1372z^2$
III	0·1056	$0·501,693 - 0·011,8074z + 0·000,0728z^2$
IV	0·0448	$0·546,143 - 0·013,8269z + 0·000,0873z^2$

By simply substituting the number of years of life z, we can find the value of the regression at any age.

5. *Illustrations of these Results.*—(i.) What is the probable family of an English mother dying at 40 ?

(*a*) gives 4·93, (*b*) 5·00, and (*d*) 5·24, all of which might equally well have been read off on the diagrams. The actually observed number is considerably in excess of all these, *i.e.*, 6·23. In fact, if an English mother lives to 40 years, she will, on the average, have very nearly completed her family. For an American woman (*a*) gives 4·16, (*b*) 4·54, and (*d*) 4·64. But if she lives another ten or twenty years she will probably have a family of ·5 or even 6.

(ii.) Compare the strength of the relationship between duration of life and size of family for American fathers dying at 40 and 70 respectively.

We find the slope of the cubical parabola at the points corresponding to 40 and 70 years to be 0·1459 and 0·0249 respectively. The mean regression for the whole of life is 0·1056 ; for the first fifty years 0·1683, and for the last fifty 0·0437 (see Table I, and reduce to year as unit). It thus appears that the influence of mere number of years as

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* It has been suggested that this is due to the nature of the record, there being a tendency to enter only the children who survive their parents. Thus the longer the latter live the fewer would be the offspring entered. In other words, we should be under-estimating the correlation between fertility and longevity. But the Quaker birth-records include all children, and their system is uniform. There does not appear any reason on this ground for English and American returns differing so sensibly.

compared with the physique which tends to longevity has an effect on fertility of about 5 or 6 to 1.

(iii.) Weismann has suggested that it may be an advantage to a species that its duration of life should be shortened.   This is not, *à priori*, confirmed for the case of man in the American series : the longer the parents live the greater the number of their offspring.   But if we can lay any stress on the bend-in for the English mothers, and on the similar but less marked tendency for the English fathers, we might argue that reproductive selection was possibly in England working against extreme longevity, although favouring parents living till 65 or 70.   Indeed those who rush rapidly to brilliant but not over-stable conclusions might emphasise Weismann's views by showing how in an old community, with much greater pressure on the material resources, there is a tendency to reduce the fertility of the long-lived parents ; while in a new community, with plenty of food and occupation for all, the longest-lived parents are the most fertile !   However, all that we can safely say is that there is a marked difference between English and American parents, and that this distinguishing characteristic is almost equally visible if we take opposite sexes of such diverse classes as English Friends and English country gentlemen.   We would leave to further investigations its true interpretation.

6. Admitting a substantial correlation between length of life and fertility, it is of great interest to investigate what effect, other things being equal,* reproductive selection would have in modifying the duration of life.

The following table gives the mean length of life of parents taken singly and of parents weighted with their offspring :—

Table IV.—Mean Duration of Life of Parents in Years.

Series.	Unweighted parents.	Weighted parents.	Progression.
I	53·292	59·920	6·628
II	61·183	63·839	2·656
III	58·086	63·082	4·996
IV	63·577	65·510	1·930

Now these are substantial differences even in the case of the English parents (II and IV), but they are very large differences in the case of the American parents (I and III).   If we suppose no assortative mating on the basis of characters tending towards longevity, then it is easy to

* Omitting, for example, the effect of natural selection as evidenced possibly in a greater death-rate in large families, &c.

obtain a rough approximation to the effect of reproductive selection in modifying the duration of life. It has been shown* that if there be no assortative mating the average deviation, h_1, of an array of offspring from the mean of the general population of offspring due to parents deviating h_2 and h_3 from the means of the general populations of parents is given by:

$$h_1 = r_{12}\frac{\sigma_1}{\sigma_2}h_1 + r_{13}\frac{\sigma_1}{\sigma_3}h_2,$$

where r_{12} and r_{13} are coefficients of parental inheritance, and σ_1, σ_2, σ_3, the standard deviations in offspring and parents for the character in question. When that character is longevity our data are not yet complete, but two of us have shown that the value of $r_{12}\sigma_1/\sigma_2$ for father and son, *i.e.*, the regression coefficient for inheritance of duration of life, is about 0·1682,† if the sons die having lived at least 21 years. We have not yet completed our data for the inheritance of the duration of life in the case (i) of minors, or (ii) in the case of the female line, although we have nearly reached the requisite amount of material. Hence the following statements must be taken as tentative and suggestive only. We will assume 0·1682 to be the regression coefficient for both sexes, and *for all ages of the offspring, minors or adults.* In this case if m_1 be the mean of the unweighted and m_2 of the weighted fathers, m_1' of the unweighted and m_2' of the weighted mothers, we should expect an increased duration of life in the offspring due to reproductive selection of

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\begin{aligned}
h_1 &= 0\text{·}1682\,(m_2 - m_1) + 0\text{·}1682\,(m_2' - m_1') \\
&= 0\text{·}1682\,(6\text{·}628 + 4\text{·}996) \left.\right\} \text{for the Americans} \\
&= 1\text{·}9551 \\
&= 0\text{·}1682\,(2\text{·}656 + 1\text{·}900) \left.\right\} \text{for the English} \\
&= 0\text{·}7714
\end{aligned}
$$

Thus the increased duration of life would be about 2 years per generation from the American data, and about 9 to 9·5 months per generation from the English data.

The result for the American series shows us how an especially low expectation of life, due possibly in this case to some family character,‡ will be rapidly raised by reproductive selection, if there be no opposing

* 'Phil. Trans.,' A, vol. 187, p. 288.

† 'Roy. Soc. Proc.,' vol. 65, p. 297. The Landed Gentry would appear to be closer than the Peerage to our present material.

‡ It is by no means certain that this is the true view of the case. We have seen that the American women have their maximum mortality in early middle-life, and only a secondary maximum at 70. The maximum mortality of the table prepared by J. P., F.R.S., for the years 1728–57 ('A Collection of the Yearly Bills of Mortality from 1657 to 1758 inclusive,' London, 1759) occurs about 41 years, and there is no evidence of a maximum at 70 at all. Thus the American data appear to resemble London data of two centuries back.

factor of evolution.   The English results on the other hand show us a small but sensible tendency in reproductive selection to prolong the duration of life.   Allowing three generations to a century, we might expect the duration of life to be raised about 2 years in a century by this factor of evolution.

In making this statement we are supposing that parents are not a short-lived selection out of the general adult population.   There seems no reason why they should be, and we have some statistics to show they are not.   Thus for the 'Peerage' and 'Landed Gentry' we have shown that for fathers and sons living 20 or 25 years and upwards, the age at death of the father is substantially greater than that of the son.*   Further, from data for the Society of Friends, Miss Beeton has found the average age at death of women in general to be 59·831, and the average age of mothers at death to be 59·793, sensibly the same. In the table for 1871 to 1880 given by the Registrar-General, the expectation of life of women in general at 20 years of age is given as 41·66 years, or the average duration of life is 61·66 years.   This is only very slightly greater than our average† for English mothers above, i.e., 61·183, and substantially less than our average for mothers weighted with their offspring, i.e., 63·082 years.   Again, the general population of males of 20 had (1871–80 returns) an average life of 64·48 years, which is not comparable with our 'Landed Gentry's' sons surviving 20 with an average life of 60·915 years, but with that of their fathers, i.e., 65·96 years.   We do not think, therefore, that parentage, in particular maternity, corresponds to any shortening in the expectation of life.   Thus reproductive selection appears to indicate a real increase in the expectation of life. Such an increased expectation of life is usually considered to have come into existence during our century owing to better sanitary conditions, greater care of the sick and invalided, &c., &c.   Its exact estimation is a matter of some difficulty.   We find F. G. P. Neison,‡ working on the Registrar-General's returns before 1841, gives (Table D, p. 8) expectations of life from 10 years onwards.   For males of 20 and 25, his mean durations of life are 60·69 and 62·35 ; for females of 20 and 25, 61·60 and 63·36 respectively.   These are not substantially less than the Registrar-General's returns for 1881 to 1890, which gives males 60·27 and 61·28, females 62·42 and 63·50 respectively.   In fact, the males show reduction.   If we stick to the Registrar-General's returns as given for three different periods, and presumably more comparable with each other than with Neison's work, we have the following results :—

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* 'Roy. Soc. Proc.,' vol. 65, p. 297.

† The average age at death of mothers must in our case closely give the expectation of life of women of 20, for there are few marriages below 20, and we have in our tables included all cases of sterile unions.

‡ 'Contributions to Vital Statistics,' London, 1846.

Expectation of Life.

Age.	1838–54.		1871–80.		1881–90.	
	♂.	♀.	♂.	♀.	♂.	♀.
0	39·91	41·85	41·35	44·62	43·66	47·18
20	39·48	40·29	39·40	41·66	40·27	42·42
25	36·12	37·04	35·68	37·98	36·28	38·50

Here there is an increased expectation at birth for males, but very small increases between the first and last periods at 20 and 25. For females there is an immense increase at birth and sensible increase in the other cases. Possibly a good deal of this may be due to more exact returns for the ages of women being now obtainable.

If we take the earliest Table of the Probabilities of Life, that deduced by J. P., F.R.S., for the bills of mortality in London for 1728 to 1757, and printed in the work cited on column 5, we find the number of deaths of 1000 persons born given for each year of life, male and female being combined. According to the Registrar-General's returns for 1881–90 of 1000 persons born, 728 survive to 20 and 709 to 25, but from J. P.'s table only 485 survive to 20 and 448 to 25. This tremendous mortality of infancy and youth was probably largely a *selective* death-rate. We find accordingly the expectation of life at birth to be only 25·59 years; at 20, however, to be 49·56 years; and at 25 to be 51·30 years.* These results are for London, not for England in general, but making all possible allowances for the difference between city and country, they suggest a most stringent selection. An increased expectation of life at birth of anything like 25 years in less than two centuries could not be achieved even at the American rate of two years per generation. Nor is it possible that the whole of the increase in the Registrar-General's returns for expectation of life at birth for the periods 1838–54 and 1881–90—an increase of somewhere about four to five years—could be due to reproductive selection, unless we suppose the correlation between age at death of minors and of their parents to be considerably greater than 0·1682. On the other hand, if we confined our attention to adults of 20 to 25 of both sexes, we have, roughly, an increase of about a year in the expectation of life, and this result with nine months per generation could easily have been reached within the two-generation period in

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* We do not know how J. P.'s table was deduced, but we got the above results by averaging the years lived by those surviving at any age out of the 1000 born.

question. Generally, we may conclude that the data are not very suitable for real purposes of comparison, but that there is nothing in them opposed to the suggestion that a sensible part of the increased duration of life of this century may be due to the inheritance of longevity and the correlation of longevity with fertility.   Further determination of the inheritance of duration of life in the case of minors may help to throw additional light on the matter.

7. The following method of illustrating the influence of longevity on fertility may serve to impress the matter on the reader :—

In Series I the longer-lived moiety of the mothers produce 64·0 per cent. of the children, and the shorter-lived moiety 36·0 per cent.

In Series III the longer-lived moiety of the fathers produce 61·1 per cent. of the children, and the shorter-lived moiety 38·9 per cent.

In Series II the longer-lived moiety of the mothers produce 55·2 per cent. of the children, and the shorter-lived moiety 44·8 per cent.

In Series IV the longer-lived moiety of the fathers produce 53·5 per cent. of the children, and the shorter-lived moiety 46·5 per cent.

Thus, while the results are all very sensible, those for the American parents are markedly so.   In both American and English statistics the influence of longevity on the fertility of the mother is greater than its influence on the father.

8. *Concluding Remarks.*—A somewhat widespread view of evolution stops at the survival of the fitter without discussing the mode whereby the less fit leave no, or fewer, offspring than the fit.   Of course, if the unfit are exterminated before adult life, there is no chance of their reproducing themselves.   It has been shown in the second paper of this series that a selective death-rate does exist for adults, so that the whole work of selection does not take place before the reproductive stage is reached.   But Miss Beeton's data for the correlation of duration of life in the case of brethren dying as minors seem to show that the selective death-rate for children is rather less than greater than its value for adults.*   Hence, for the reduction or extermination of stock unsuited to its environment, we should have to look largely to selection in the adult state.   In the present paper we have made what we believe to be the first quantitative determination of how a selective mortality reduces the numbers of the offspring of the less fit relatively to the fitter.   In the case of life under wild conditions, the correlation between fertility and power of surviving would probably be far greater.   But for such life it is almost impossible to get statistics of this nature ; we are thrown

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* The matter is still under investigation, so that this conclusion is stated subject to modification.   Of course, the selective death-rate among children may largely remove those not weak from *inherited* constitution, but by physical or physiological accident.   These our method of investigation would throw into the non-selective death-rate.

back upon measuring the effect in man, and thus obtaining what may well be considered as a minimum value of the influence under discussion.

In the course of our investigations we have seen that the relationship between fertility and duration of life does not cease with the fecund period. We thus reach the important result that characters which build up a constitution fittest to survive are also characters which encourage its fertility. This result is of great value from the standpoint of the differentiation of type, where it is absolutely necessary that the fittest to survive should also be the most fertile.* On the other hand, we note that duration of life is a character capable of modification by reproductive selection, and we suggest that a considerable part of the increased expectation of life observed in recent years may be due to this cause. In the case of the American statistics, we see at once how it can replace a remarkably short-lived stock by a longer-lived stock, the bulk of the offspring coming from the longer-lived members.

* 'The Grammar of Science,' second edition, pp. 448—9.

Table V.—Mothers and Offspring. Series 1.

Age of mother at death.

Number of offspring	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Totals
0	3	3	1	1	3	5	2	0	0	3	3	1	1	2	2			24
1	19	47	25	9	6	5	2	2	4	4	3	1	0	2	1	1		130
2	5	20	26	13	8	10	8	6	5	8	7	6	13	5	2	0		122
3	1	7	21	21	15	12	9	5	5	8	5	3	4	8	1	0		134
4	1	8	15	15	15	9	8	5	6	6	6	10	9	7	2	1		111
5		1	6	14	10	10	5	4	11	5	12	6	11	7	3	0		106
6		1	4	12	7	8	3	6	6	7	5	5	9	2	2	2		85
7			1	18	5	8	7	8	10	5	6	12	5	10	6	1	2	91
8				3	8	6	8	5	6	5	9	9	6	2	2	1	1	81
9				2	7	6	3	8	7	10	10	13	8	7	2	0	0	77
10				1	4	4	4	3	3	3	6	6	5	1	1	0	0	58
11					0	4	0	0	1	2	2	2	3	4	0	1	0	23
12					0		2	1	3	2	5	3	4	1	0	0	0	24
13					1		1	0	1	2	1	0	0	1	0		1	15
14					0		0	0	0	2	3	0	0	0	0			6
15					0		1	0	1	0	0	0	0	0	1			2
16					1		0	1	0	0	0	0	0	0	1			2
17							0	0	0	1	0	0	0	0				2
18							1	0	0	0	0	0	0	0				2
Mothers, totals..	29	87	99	109	90	87	64	54	69	73	83	77	78	59	26	7	4	1095
Offspring, totals	36	151	261	478	450	437	370	331	436	447	547	590	547	398	212	50	35	5776

Table VI.—Mothers and Offspring. Series II.

Age of mother at death.

Number of offspring	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	Totals
0	0	0	0	0	0	0	2	0	2	1	2	0	2	2	0	1			12
1	5	19	17	5	5	4	4	2	7	6	6	7	7	5	4	0			103
2		10	12	5	1	7	7	4	8	8	11	6	5	3	5	3			95
3		4	7	7	4	1	5	3	10	12	8	7	9	4	3	0			84
4		1	7	12	7	4	9	7	7	8	9	13	9	8	4	1			106
5		0	3	11	18	10	6	15	5	15	12	13	12	11	3	0			134
6		1	5	8	5	7	7	4	4	9	8	13	9	9	6	0	0	1	96
7			2	8	5	5	2	5	6	9	13	12	11	10	5	1	1		95
8			1	5	2	14	0	1	10	8	6	8	8	10	4	1			78
9			3	0	8	3	2	9	3	7	10	13	4	9	5	0			76
10				2	3	3	2	5	3	8	10	10	6	4	1	0			57
11					4	1	2	2	4	5	5	4	3	3	1	0			34
12					1	1	1	4	2	4	3	5	3	2	0	0			26
13					1	2	0	1	1	2	3	1	1	1	1	0			16
14					0	0	1	0	1	3	4	1	1	0	0	0			11
15					0	0	0	0	1	0	1	0	1	0	1	1			5
16					1	0	0	0	0	0	0	0		0	1				3
17								0	0	0	0	2							2
18								1	0	0	0	0							1
19												1							1
20												1							1
Mothers, totals	5	35	57	63	65	62	50	63	74	105	111	117	94	81	44	8	1	1	1086
Offspring, totals	5	61	184	303	405	382	241	421	419	660	726	804	584	505	267	40	7	6	6020

Table VII.—Fathers and Offspring. Series III.

Age of father at death.

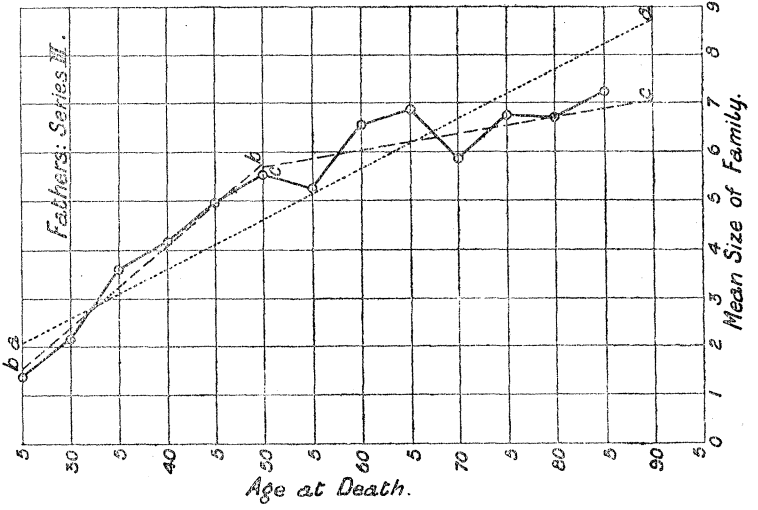| Number of offspring	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Totals.
0	0	7	4	1	0	4	3	4	2	2	4	4	3	0	0	0	0	38
1	1	24	15	5	11	13	4	8	3	5	4	0	1	1	2	0	0	97
2	1	9	24	16	10	11	7	8	10	6	6	8	6	2	0	0	0	124
3		3	12	14	12	7	7	8	7	6	10	9	7	5	0	2	1	110
4		1	4	13	14	8	15	11	4	8	9	11	4	6	1	0	1	110
5		1	4	12	9	11	8	12	11	11	18	10	10	2	1	1	0	121
6				5	10	6	6	7	10	6	8	10	10	8	1	0	1	88
7				2	6	9	3	7	10	11	8	8	9	9	1	1	0	84
8				1	2	6	7	5	10	8	9	8	12	11	2	2	0	83
9				1	2	6	4	5	7	10	13	13	5	5	1	1	0	72
10					1	5	6	7	7	8	6	7	6	4	1	2	1	61
11					1	4	2	2	8	5	0	7	4	5	1	1	0	40
12						1	3	2	2	4	1	4	5	2	0	1	1	26
13							1	0	1	3	1	3	2	3	1	0	0	15
14								1	1	1	1	3	0	0	0	0	0	7
15										0	0	0	0	0	0	1	1	4
16										2	0	0	1	0	0	0	0	3
17											1	0	0	0	0	0	0	1
Fathers, totals ..	2	45	63	70	78	91	76	87	94	96	99	105	85	63	12	12	6	1084
Offspring, totals	3	60	135	252	325	450	419	458	618	657	581	710	570	456	83	101	50	5928

Number of offspring.

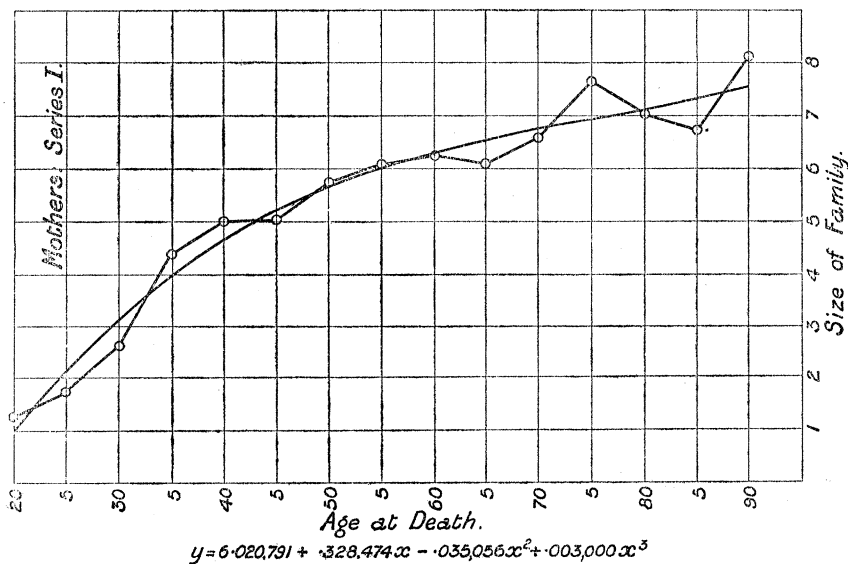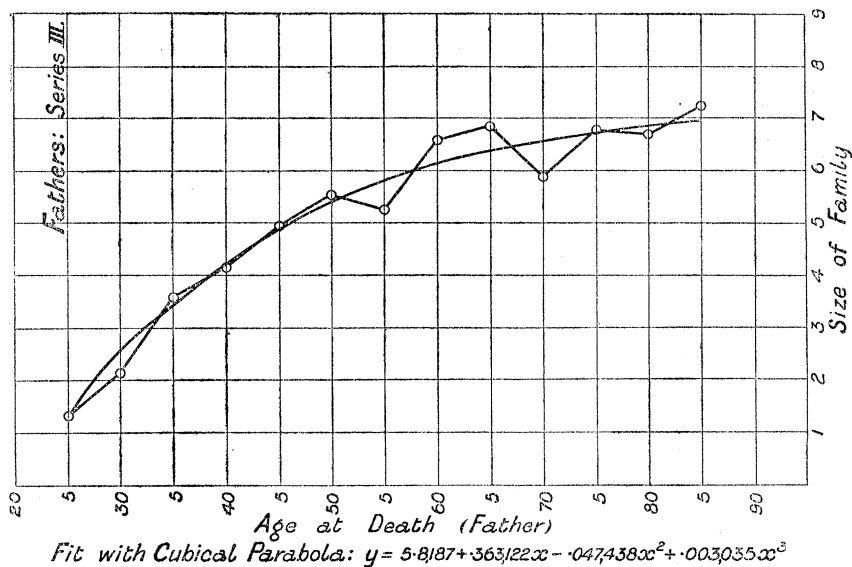Table VIII.—Fathers and Offspring. Series IV.

Age of father at death.

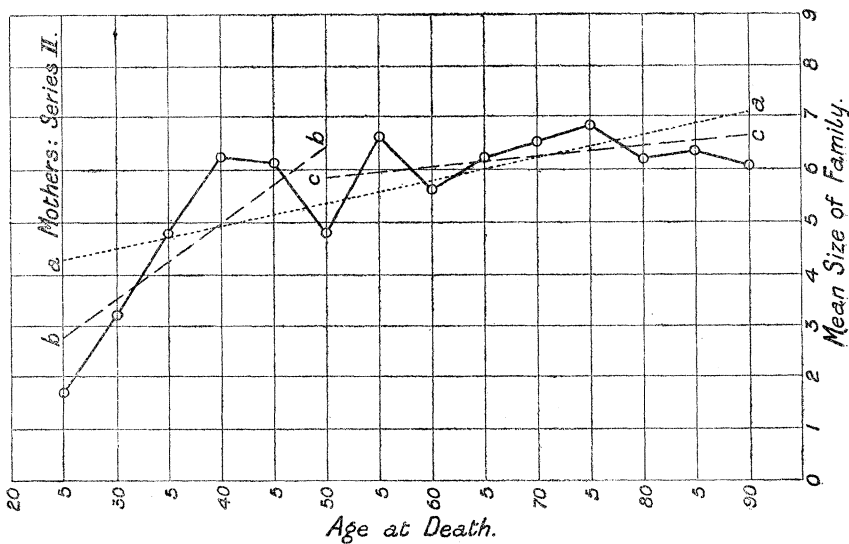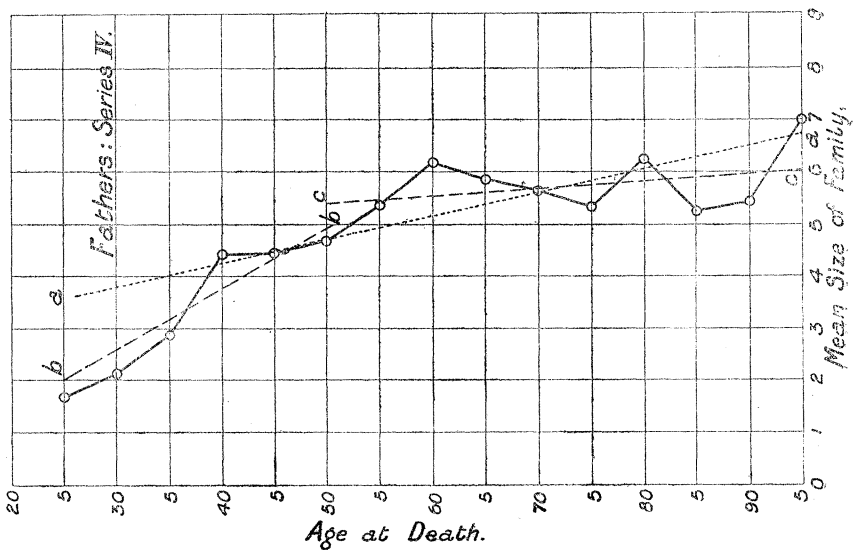| Number of offspring.	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	Totals.
0	2	5	6	2	10	11	7	4	6	6	7	7	6	2	1	0	0	82
1	2	3	5	1	4	4	3	8	6	5	8	1	1	2	0	0	0	53
2	1	4.5	4.5	5	5	5	4	5	3	11	9	6	4	0	0	0	0	67
3	1	3	7	8	7	7	10.5	9	14	10	11	13	6	3	0	0	0	109
4	0	2	5	7.5	6	8	10	8	15	12	19	18.5	5.5	4	0	0	0	121
5	1	2	3	6	9	15	10.5	17.5	16	18	16	7	9	1	0	0	1	131
6		1	1	6	9	6	11	10	14	13.5	19.5	5	8	4	0	0		109
7			1	1	3	4	4	10	12	13	6	13	1	4	0	0		72
8			1	3	6	5	3	11	14	15	8	13	2	4	1	0		85
9			1	0	1	4	8	9	7	7	2	12	4	1	0	0		50
10				0	4	4	6	7	3	3	7	5	5	1	0	0		49
11				2	0	1	4	3	2	2.5	1	6	0	0	1	0		22
12					0	2	1	5	4	2	5.5	0	1	1	0	0		23
13					0	0	0	2	0	1	2	4	0	0	0	0		10
14					1	0	0	1	3	0	0	1	1	0	0	1		9
15								0	0	0	0	2.5	0.5	0				3
16								1	1	0	0			0				2
17								1	1	0	0							2
18											0							0
19											0							0
20											1							1
Fathers, totals..	7	20.5	35	41.5	65	76	81.5	108.5	121	122	122	114	54	27	3	1	1	1000
Offspring, totals	12	45	102	184	290	357	439.5	672.5	712	637	649	713.5	284.5	147	21	14	6	5336

American Parents.   Regression Straight Lines.   (Figs. 1 and 2.)
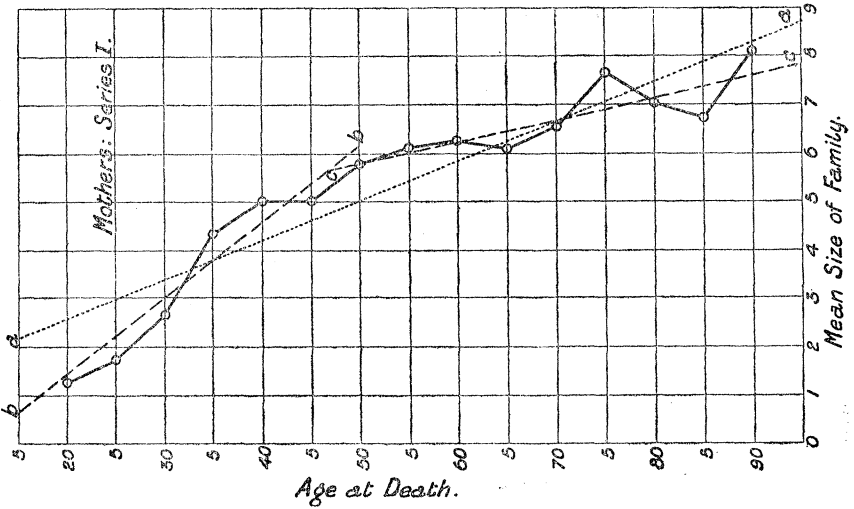
American Parents. Regression Cubical Parabola. (Figs. 3 and 4.)

Fathers: Series III.

Size of Family

Age at Death (Father)

Fit with Cubical Parabola: $y = 5.8187 + .363{,}122x - .047{,}438x^2 + .003{,}035x^3$

Mothers: Series I.

Size of Family.

Age at Death.

$y = 6.020{,}791 + .328{,}474x - .035{,}056x^2 + .003{,}000x^3$

English Parents.   Regression Straight Lines.   (Figs. 5 and 6.)

English Parents. Regression Cubical Parabola. (Figs. 7 and 8.)

Fathers: Series IV.

Age at Death.

Size of Family.

$$y = 5\cdot50{,}752 + \cdot153{,}4035x - \cdot041{,}940x^2 + \cdot003{,}636x^3$$

Mothers: Series II

Age at Death.

Size of Family.

$$y = 6\cdot409{,}225 + \cdot079{,}120x - \cdot052{,}7195x^2 + \cdot005{,}717x^3.$$