

**THE ANCESTRY OF
THE LONG-LIVED**

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THE RATE OF LIVING

CONSTITUTION AND HEALTH



10 TRULY LONGEVOUS PERSON

THIS PHOTOGRAPH OF MRS. EMILY SHAW GRIFFITH WAS MADE WHEN SHE WAS 100 YEARS OLD. SHE LIVED TO BE OVER 102 YEARS OLD. WHILE HER PORTRAIT EXHIBITS THE WRINKLING CHARACTERISTIC OF OLD AGE, IT SHOWS AT THE SAME TIME A TRULY REFRESHING GENERAL ALIVENESS AND SPRIGHTLY PARTICIPATION IN THE SITUATION. IT IS AN EXCELLENT EXAMPLE OF THE FACT THAT NOT ALL CENTENARIANS ARE TOTTERING COMATOSE TO THE GRAVE. MRS. GRIFFITH WAS THE MOTHER OF SIX CHILDREN, AND GRANDMOTHER OF FOUR. WHEN WE LAST HEARD FROM HER SHE WAS KEENLY INTERESTED IN ALL THAT WAS GOING ON IN THE WORLD ABOUT HER, OF WHICH SHE HAD BEEN A RESIDENT FOR SUCH A VERY LONG TIME.

THE ANCESTRY OF THE LONG-LIVED

BY

RAYMOND PEARL and RUTH DeWITT PEARL

The Johns Hopkins University



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PREFACE

This book represents one stage in the development of the general program of investigation of human life duration in the Department of Biology of the School of Hygiene and Public Health of The Johns Hopkins University. The results of this particular phase of the work have already appeared in part as No. VI of the series of *Studies on Human Longevity* in the journal *Human Biology*. Owing to limitations of space it was impossible to present all our data and results in journal publication.

In particular we have added two chapters (IV and IX). The first of these deals in some detail with a discussion of the effects upon the age distributions of the progeny of certain types of selection of the ancestry. The increasing use by biostatisticians of family data for the study of various problems makes such an investigation as that reported in Chapter IV highly desirable at this time, quite apart from its relation to the present study. Chapter IX presents a detailed analysis of the relation between the ages of groups of living individuals and the summed ages at death of their six immediate ancestors, for the purpose of making possible a better judgment of the significance of the results presented relative to the inheritance factor in longevity.

We are conscious of the fact and regret it, that this book cannot be looked upon as easy reading. It is a report of an extensive and extremely laborious piece of research upon an involved and difficult problem in human biology, and the story of the results necessarily has to be told mainly in figures and charts. But, on the other hand, we believe that any reader who is really interested in the problems of human longevity will have no difficulty in following the reasoning and understanding the results if he will take the trouble to read the book carefully.

It may be a convenience to the reader to have assembled in one place the bibliographic references to the earlier studies in this series. They are as follows:

Studies on Human Longevity

- I. A note on the inheritance of duration of life in man. By R. P. *Amer. Jour. Hyg.*, Vol. 2, pp. 229-233, 1922.

- II. Preliminary account of an investigation of factors influencing longevity. By R. P. *Jour. Amer. Med. Assoc.*, Vol. 82, pp. 259-264, 1924.
- III. Longevity: a pedigree. By R. P. *Human Biology*, Vol. 3, pp. 133-137, 1931.
- IV. The inheritance of longevity. By R. P. *Human Biology*, Vol. 3, pp. 245-269, 1931.
- V. Constitutional factors in mortality at advanced ages. By R. P. and T. Raenkhram. *Human Biology*, Vol. 4, pp. 80-118, 1932.
- VI. The distribution and correlation of variation in the total immediate ancestral longevity of nonagenarians and centenarians, in relation to the inheritance factor in duration of life. By R. P. and Ruth DeWitt Pearl. *Human Biology*, Vol. 6, pp. 98-223, 1934.

In the preparation of this book we are indebted to Dr. John Rice Miner and Miss Marjorie E. Gooch, for aid in a variety of ways; to Prof. Lowell J. Reed for critically reading the major part of the manuscript; and to the late Mrs. Emily Shaw Griffith for permitting us to use her charming portrait as a frontispiece to this volume.

Good Friday

1934

R. P. and R. D. P.

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CHAPTER I

THE PROBLEM



WHILE the time duration of the life of an organism from its birth to its death varies from individual to individual, the mean or average value of this biologically important characteristic is rather constant for the particular species, variety, race, or otherwise significantly differentiated group. In the case of man we use the word "longevity" as generally synonymous with "duration of life," but also with the special connotation of great or extreme duration of life. In any attempt at a critical biological analysis and discussion of this characteristic we are at once confronted with the question of what shall be regarded as extreme longevity. What lower limit in years of duration of life shall be taken as indicative of biologically noteworthy or significant longevity? A precise and standardized definition of this concept can only be derived from the examination of life tables. We are accustomed to think of 95 years of age as extreme longevity, but if half of all persons ever born lived to that age it would not be so regarded. Plainly what determines the matter is not so much an absolute age *per se* as it is the proportion of individuals in a particular group who reach that age. The degree of rarity of its occurrence decides what we shall regard as great longevity. In our work on the problems of human longevity we long ago decided to regard nonagenarians and centenarians as the truly longevous. The relative numbers of such persons attaining this status in some twenty different racial and demographic groups are shown in a table, age 92 being the exact year chosen for purposes of tabulation. In this same table are shown the mean or average life table durations of life (complete expectation of life at birth) for the same groups, and finally in the last two columns of the table are given the mean expected total durations of life of persons who live to the age of 92 years. Technically these last two columns give the $e_{92} + 92$ values from the life tables. For convenience in printing and reference we call these CML (92) values, the symbol meaning "computed mean longevity of persons living at age 92." The

Expectation of Life at Birth, Number of Survivors at Age 92 Out of 1000 Born Alive, and Expected Mean Total Longevity of Survivors at Age 92, for Various Racial and Demographic Groups

ITEM NO.	GROUP AND DATE	EXPECTATION OF LIFE AT BIRTH IN YEARS		NUMBER OF SURVIVORS AT AGE 92 OUT OF EACH 100 BORN ALIVE		EXPECTED MEAN TOTAL LONGEVITY OF PERSONS LIVING TO AGE 92. CML (92). (YEARS)	
		Males	Females	Males	Females	Males	Females
1	Kansas, U. S. A. Whites, 1919-20	59.82	61.02	1.616	0.915	93.90	92.97
2	Utah, U. S. A. Whites, 1919-20	55.39	58.61	.221	.469	92.00	92.23
3	U. S. A. Aggregate whites, ³ 1919-20	55.35	57.52	1.348	1.861	94.55	94.62
4	Australia, 1901-10	55.20	58.84	.840	1.999	94.31	94.60
5	Norway, 1901-10	54.84	57.72	2.089	3.102	94.73	94.90
6	Sweden, 1901-10	54.53	56.98	1.181	1.995	94.30	94.54
7	U. S. A. whites in Orig. Reg. States, 1919-20	54.05	56.41	.924	1.575	94.10	94.63
8	Chicago, Ill., U. S. A. Whites, 1919-20	52.36	55.49	.991	1.173	94.22	93.92
9	San Francisco, Cal., U. S. A. Whites, 1919-20	51.76	56.50	.004	0.768	92.75	93.85
10	Holland, 1900-1909	51.00	53.40	.755	1.184	93.60	93.90
11	U. S. A. Whites in Orig. Reg. States, 1909-11	50.23	53.62	.829	1.267	94.70	94.67
12	U. S. A. Whites in Orig. Reg. States, 1901-10	49.32	52.54	.798	1.281	94.60	94.74
13	Switzerland, 1901-10	49.25	52.15	.295	.477	94.12	94.21
14	England, 1901-10	48.53	52.38	.538	1.163	94.32	94.66
15	U. S. A. Negroes in states with more than 5 per cent Negroes, 1919-20	46.39	45.46	1.411	1.077	94.77	94.20
16	France, 1898-1903	45.74	49.13	.375	.830	95.05	95.64
17	Germany, 1901-10	44.82	48.33	.307	.549	94.10	94.36
18	Italy, 1901-10	44.24	44.83	.228	.254	93.70	93.70
19	Japan, 1898-1903	43.97	44.85	.275	.535	93.90	94.00
20	India, 1901-10	22.59	23.31	.002	.002	93.00	92.84
21	Means (all cases)	49.47	51.95	.751	1.124	94.04	94.16
22	Means (India omitted)	50.88	53.46	.791	1.183	94.09	94.23

³This includes approximately 74 per cent of the total population as of the dates mentioned.

table is arranged in descending order of expectation of life at birth for the males. The data in the table are compiled from two standard sources.*

The items in the table have been chosen solely for the purpose of illustrating certain general points about human longevity, necessary to be clearly understood before any penetrating biological analysis of the matter can be profitably undertaken. They represent a rather wide range of races and conditions. Naturally vastly more data of the same sort are available, but in the space here available it is not expedient to include more. Furthermore it is unlikely that any essential point brought out by the table would be seriously altered if it included 200 life tables instead of 20.

The first point which is apparent from an examination of the table is one that has already been noted in general terms, namely that *average* duration of life (expectation of life at birth) is relatively constant. Leaving India out of account for the moment, the expectations of life for both males and females do not deviate from their respective means by more than about 10 years as a maximum either way. Generally speaking it is fair to say that, under the environmental conditions surrounding civilized man in the first quarter of the 20th century, it is a species characteristic of *Homo sapiens* to live about 50 years on the average, with a maximum fluctuation either plus or minus of about 10 years from that figure. Even if India, with its appalling lack of sanitation and of adequate nutrition, together with its excessive overcrowding and climatic difficulties, be taken into the reckoning it appears that the best group in the table (Kansas whites) has an expectation of life at birth only 2.6 times greater for either males or females. And if instead of India we take Japan, standing next above it in the table, for comparison, it is seen that Kansas has an expectation of life at birth only 1.4 times greater for either males or females.

But the case is quite different when we examine the number of people out of a hundred born alive who succeeded in surviving until they are 92 years old. Here the relative constancy shown by the expectations of life at birth is replaced by a marked tendency to wide variation. The rarity of nonagenarians is indicated by the fact that on the average (Item 21) only about three-fourths of a male person and

* Glover, J. W. United States Life Tables. *Washington*, 1921.
Foudray, E. United States Abridged Life Tables, 1919-1920. *Washington*, 1923.

slightly over one female person out of the hundred of each starting together at birth is alive at age 92. The group of highest survivorship at that age (Norway) has over 1000 times as many male survivors at 92, and over 1500 times as many female survivors as the group of lowest survivorship (India). Furthermore, if we leave out India as a somewhat special case, and take Italy for comparison with Norway, it is seen that the latter country has 9.2 times as many males alive at 92 years of age, and 12.2 times as many females.

When the last two columns of the table are examined a still different state of affairs presents itself. The persons of any race or clime who live to age 92 show, as subgroups, extraordinarily little inter-group variability in their average total longevity [CML (92)]. Now it is evident that the immediate reason, things being as they are, why these extremely longevous sub-groups exhibit such small inter-group variation is because age 92 is so near the upper limit of the human life span. In a manner of speaking they have no room in which to vary much. But this is only a statistical aspect of "things as they are." Biologically the upper limit of the human life span is determined only by the inability of human beings, as now bred and environed, to live much more than 95 to 100 years.* There is no necessary theoretical or biological reason why some human beings should not have their length of living so distributed that the inter-group variability in respect of CML (92) would be of the same order of magnitude as that in respect of CML (0) now is. There simply are not sufficient numbers of such people at the present time. Possibly at some future time there may be. Actually at the present time the *inter-individual* variability of persons living at ages of 90 and beyond is shown farther on in this study to be of the order of magnitude indicated by a coefficient of variation of less than $4 \pm .1$ per cent.

The relative inter-group variabilities shown by the data of the table are as follows, measured by the coefficients of variation, with India omitted in all cases for reasons indicated above.

Male expectation of life at birth.....	= 8.64 %
Female expectation of life at birth.....	= 9.03 %
Male per-100-born-survivorship at 92	= 68.14 %

* Cf. Pearl, R. Span of life and average duration of life. *Natural History*, Vol. 26, pp. 26-30, 1926.

Female per-100-born-survivorship at 92	= 57.20 %
Male computed mean longevity of persons living to age 92 =	0.75 %
Female computed mean longevity of persons living to age 92 =	0.77 %

It is to be noted that the absolute values of these coefficients of variation are of no particular importance. It is in their comparative values that our present interest lies. It is seen that the same identical groups of human beings display an inter-group variability in number of survivors to age 92 from roughly 6 to 8 times greater than their inter-group variability in expectation of life at birth. Now a part of this greater variability in number of survivors to extreme longevity is doubtless due to the fact that the data are necessarily more meager as the upper limit of the life span is approached, but this can scarcely account for all of the difference. A considerable part of it presumably rests upon biological and specifically genetic causes. Finally these same identical groups exhibit an inter-group variability in respect of average total longevity of persons living to age 92 [CML (92)] smaller than that of almost if not quite any other character of man hitherto studied biometrically.

How are the phenomena and relationships that we have derived from standard life table data and briefly described above to be explained biologically? It is to the study of this general question that a major part of the work of our laboratory has been devoted for more than ten years. It is plainly not a matter of luck or accident that some human beings live to ages of 90 and above, while the vast majority do nothing of the kind. What we really want to find out, in sound biological terms, is why those who do are able to turn the trick.

In outlining and developing a program of research on this problem it seemed desirable first to collect as large a mass of data as feasible regarding extremely longevous persons, and then see in what respects besides longevity they differed from ordinary human beings. We have with considerable labor collected such a body of data (see Chapter II). The present study is the first to be published of what we hope will be a series of reports regarding this material regarding longevous persons, considered from various angles. It deals particularly with the genetic or inheritance factor in the attainment of great longevity.

For the purposes of the following discussion "Total Immediate Ancestral Longevity" (abbreviated TIAL, pronounced *tee-aal*) is taken to mean the sum of the ages at death of the six immediate ancestors of

an individual (father, mother, father's father, father's mother, mother's father, mother's mother). Thus if, in the pedigree shown as Figure 1, the letters within the circles of the sex symbols denote ages at death, for the individual (propositus) I,

$$TIAL_I = a + b + c + d + e + f.$$

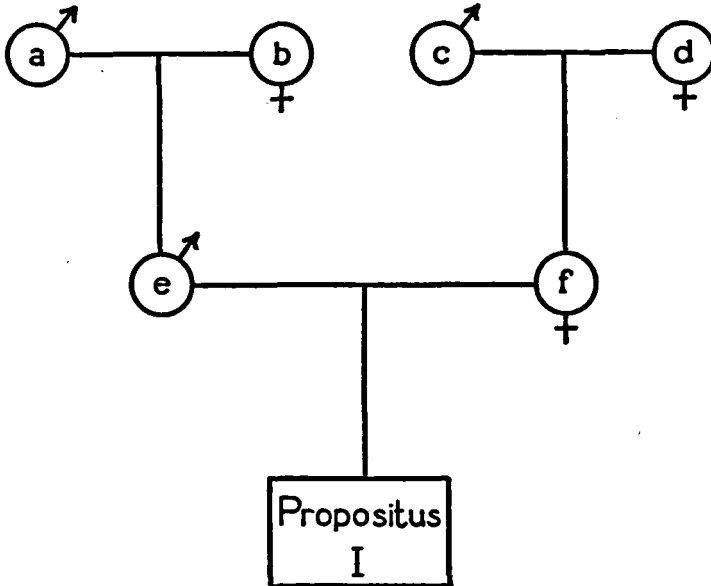


FIG. 1. A PEDIGREE TO DEFINE THE VALUE OF TIAL

TIAL is a definite attribute of biological significance pertaining to the individual (propositus) I, just as truly as his own age is one of his characters. Individuals differ among themselves in respect of their TIAL just as they differ in respect of stature. It may be said of a particular individual A, for example, that he has a stature of 6 ft. 2 in., and a TIAL of 468 years. In one important respect TIAL differs from most other characters of the individual. That is that he shares his TIAL identically with his full siblings. Each of his brothers and sisters necessarily have the same TIAL as he.

TIAL is plainly a character worthy of eugenic consideration and selection. There can be but little argument as to its biological and social worth, of the sort there can be and is about various physical and mental characters. Survival is well-nigh universally counted a biological good.

If this were not so preventive medicine and public health would be undesirable efforts. Insofar as longevity is a heritable characteristic TIAL is an attribute of prime importance.

It is evident that the value of TIAL can only vary between upper and lower limits fixed by six times the upper end of the human life span on the one hand, and six times the age of puberty on the other hand. Thus TIAL values are not likely to be found to be much above 600 years on the upper side, and the lower limit will probably not be below 90 years.² As a matter of fact neither of these approximate limits has been reached in any actual family in our collection of data. As will presently appear, the upper limit is more closely approached than the lower in our data.

Sometime ago it occurred to us to examine the variation in TIAL among a group of individuals living at ages of 90 years and over. Such individuals constitute a highly selected group of human beings, in the sense that they have succeeded in living a much longer time than the generality of mankind. No doubt various factors, both internal and external to the individual, contribute to the achievement of this great longevity. It is definitely known³ that heredity, among other things, plays an important rôle in the matter. But there is need of much more investigation of this factor in the case. It is desirable to study the genetics of longevity from as many different angles as possible. It is from this point of view that we approach the investigation of TIAL in extremely longevous people.

What, then, is the form of the frequency distribution of variation in TIAL for extremely longevous individuals, nonagenarians or centenarians, and how does it compare with that for people in general, not selected for extreme longevity?

This is the first problem of the present study. As will be seen it leads to other matters, particularly those relating to the variation and correlation of various combinations of its component elements.

²For a number of years we have been interested in collecting records to the end of finding the youngest known *living* age at the time of becoming a grandparent. Around 29 years is the lowest figure to come to our attention, and it seems unlikely that any record much lower will be found. Of course the age of *dead* grandparents, with which we are alone concerned here, may be anything from puberty on. We have assumed an age of 15 years for each ancestor in the estimated lower limit of TIAL given above.

³Cf. Pearl, R. Studies on human longevity. IV. The inheritance of longevity. Preliminary report. *Human Biology*, Vol. 3, pp. 245-269, 1931.

CHAPTER II

THE MATERIAL



THE data here discussed come from two sets of material in the archives of the Department of Biology. That relating to the extremely longevous individuals living at ages of 90 years and above is derived from our collection of case histories of extreme longevity.⁴ This collection has been in process of formation during the past ten years and now includes in total over 1500 finished cases, and about a thousand more still in process of completion. They have been got by the questionnaire method. Originally the questionnaires were sent only to living persons alleged to be 95 years of age and more. As the work has gone on, however, we have been compelled by a sort of social pressure to include some cases between 90 and 95 years of age. The final form of the questionnaire after various revisions is shown in reduced facsimile in Figures 2-5.

These blank forms have, in most cases, been actually filled out by some relative of the aged individual—son, daughter, niece, nephew, or other—in consultation with the living propositus. When the blank is returned the work upon it in the laboratory begins. First every item of the record is gone over critically, and with the attitude that the data are incorrect unless definite evidence of their correctness can be produced. This has two results. The first is that many of the returned blanks are discarded because confirmatory evidence does not develop. The other is that a long correspondence with the individual and his or her relatives is entered upon to bring out information that will, we hope, make the case in the end satisfy our critical standards. If the matter turns out this way, the case is eventually finished and goes into the file for permanent preservation and use. If it does not the case is dropped, and goes into the reject file or the waste basket.

The material includes persons from a great variety of ranks and walks of life. Originally they stem mainly from the racial stocks of northern and central Europe, but mostly have been a long time in this

⁴Pearl, R. Preliminary account of an investigation of factors influencing longevity. *Jour. Amer. Med. Assoc.*, Vol. 82, pp. 259-264, 1924.

ANCESTRY OF THE LONG-LIVED

RESIDENCE, OCCUPATION, ETC.	
In what PLACES have you RESIDED at different times in your life?	
Have you LIVED mostly in the COUNTRY or CITY?	
What OCCUPATIONS have you followed at different times during life?	
To what extent have you done HARD MANUAL LABOR?	
What is your RELIGIOUS FAITH?	
To what RACE STOCK (English, Scotch, Irish, German, French, etc.), do you chiefly belong?	
What is your HEIGHT?	AVERAGE WEIGHT?
How has your WEIGHT CHANGED since you were 25 years of age?	
What, in general, has been your BUILD DURING ADULT LIFE?	
A. THIN AND LEAN?	
B. MODERATELY THICK-SET OR CHUNKY?	
C. DISTINCTLY FAT?	
Color of hair at age 25?	Now?
Color of eyes?	
Were you a blond or a brunette?	
BY WHOM WAS THIS BLANK FILLED OUT?	
WHAT IS YOUR RELATION TO	
PLEASE GIVE ME THE NAME AND ADDRESS OF ANY OTHER RELATIVE WHO MIGHT BE ABLE TO FURNISH ADDITIONAL OR MISSING INFORMATION	
DATE WHEN THIS BLANK WAS FILLED OUT	PLEASE TURN OVER

FIG. 5. FOURTH PAGE OF LONGEVITY QUESTIONNAIRE IN REDUCED FACSIMILE

TABLE I
*Family Histories of Extremely Old Persons Living
 at the Time of Record*

AGE OF LIVING PERSON years	NUMBER OF CASES		
	Males	Females	Total
90	82	63	145
91	49	35	84
92	62	33	95
93	37	30	67
94	43	37	80
95	77	82	159
96	76	70	146
97	56	53	109
98	45	48	93
99	46	58	104
100	75	141	216
101	31	65	96
102	15	52	67
103	14	22	36
104	11	19	30
105	2	22	24
106	2	6	8
107	4	2	6
108	1	5	6
109	..	2	2
110	..	..	..
111	2	1	3
112	..	2	2
113	..	1	1
Totals	730	849	1579

country. The age and sex distribution of the first 1579 cases (from which some may possibly still be rejected because of uncertainty as to the reliability of some of the records involved) is shown in Table 1.

Regarding this Table 1 it should be said that the distributions are in no sense random samples of the number living in the general population at the indicated ages. There has been no attempt to make them such, and the method used in collecting the material makes it impossible for them to be random samples. To get case histories of extremely longevous persons one must first have their names and addresses. Our source for these names and addresses has been primarily newspaper clippings. This means that, in the main, this material contains only extremely old persons whose great age *per se*, or something they did, or that happened to them, caused them to be written about in their local newspapers. This accounts further for the excess frequencies at ages 90, 95, and 100, in contradistinction to the usual reason for such abnormal frequencies at quinquennial ages in census returns. In the data which finally pass our critical tests we know that the persons put down as 90, or 95, or 100 years old, were in actual fact just that old, because we have definite evidence as to date of birth, etc. But why we know about these persons *at all* is because something connected with their attainment of these anniversaries was, in each case, given local newspaper publicity. On the other hand, we have no record at all of the relatively large number of persons who got no publicity when they became 90, 95, or 100 years old.

From the finished longevity histories we have extracted for this present study every single case, without any selection whatever, for which the age at death of each of the two parents and four grandparents was recorded. There were 365 such cases. They constitute what will for convenience be called the *Long. Series* in this study. The *propositi* in this series, it may be repeated for clarity and emphasis, are, in each case, persons *living* at ages of 90 years or over.

Another series of similar data, for purposes of comparison, was extracted from the Family History Records of the Department of Biology. This collection of Family History Records has been used in various investigations⁵ and the characteristics of the material de-

⁵ Pearl, R. (a) The relative influence of the constitutional factor in the etiology of tuberculosis. *Amer. Rev. Tuberc.*, Vol. 4, pp. 688-712, 1920.

scribed in detail, so that it is not necessary to say anything further about it here. In particular the characteristics of this material in respect of duration of life have been discussed in No. IV of the series of *Studies on Human Longevity*. In the present instance we extracted from the Family History Records every case in which both parents and all four grandparents were dead, and had the ages at death recorded. Since every case in the Records was taken, it is obvious that there could have been no selection *relative to the age of the propositus* to which the TIAL figure relates, except insofar as the restriction that all six immediate ancestors must be dead may imply such a selection. As a matter of fact, having taken every case in which all six immediate ancestors were dead (*i.e.*, having made the basis of selection of cases an attribute of the *ancestry*) we were compelled to make an arbitrary choice of an individual from the offspring sibship, to play the rôle of propositus (I in Fig. 1) in this series. The rule we decided upon was to take as propositus the oldest *living* individual in the sibship, because the propositus in each case in the Long. Series was living. In 7 cases there was no living

_____. (b) New data on the influence of alcohol on the expectation of life in man. *Amer. Jour. Hyg.*, Vol. 2, pp. 463-466, 1922.

_____. (c) The age at death of the parents of the tuberculous and the cancerous. *Ibid.*, Vol. 3, pp. 71-89, 1923.

_____. (d) Alcohol and Mortality. In *The Action of Alcohol on Man*, by E. H. Starling. London (Longmans, Green and Co.), 1923.

_____. (e) Alcohol and life duration. *Brit. Med. Jour.*, Vol. I for 1924, pp. 948-950.

Kacprzak, M. (f) Tuberculosis and fertility. *Amer. Jour. Hyg.*, Vol. 4, pp. 605-638, 1924.

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_____. (k) Alkohol und Lebensdauer. *Hannover* (Norddeutsches Druck- und Verlagshaus), 1930.

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sibling. In these cases we took as *propositus* the individual in the sibship who had the highest age at death.

So, then, we have for comparison in this study two series of data, in one of which the *propositus* in every case had achieved extreme longevity (living age 90+ years), and in the other of which the *propositus* in each case was not directly selected in respect of age. The latter series will be designated in this study as the FHR Series. It contains 143 individuals.

Summarily stated, we are comparing in this study two groups of living persons (the *propositi*). These two groups are exactly alike in one respect, namely that all six immediate ancestors of the individuals in each group are dead. In one of these groups (here called the Longevous Series) each one of the offspring sibships stemming from the six dead ancestors contains at least one person 90 years of age or over and still living, and for the *propositi* in this group one such nonagenarian or centenarian is chosen for each offspring sibship. In the other group (here called the FHR Series) no attention whatever is paid to the ages of the persons in the offspring sibships (but in fact no one of them happens to contain a nonagenarian or centenarian) deriving from their six dead ancestors, and for the *propositi* in this group merely the oldest living individual in each sibship is chosen (except in the seven cases where there was no living sib).

It should be clearly understood, and is here emphasized in order that there may be no misapprehension about the matter, that the FHR Series is a group of individuals selected for *comparison* with the Long. Series, and nothing but that. It is *neither* a control group in the sense that the word "control" is used in physiological experimentation for example, *nor* a random sample of any general population in any general or inclusive sense of the word "random." In the nature of the case it is *impossible* now or at any other time to obtain a group of persons who will be, in any strict or inclusive sense of the words, a random control against a series of living nonagenarians and centenarians for the purpose of studying the inheritance of longevity. The best that can be done in the premises is to *compare* the longevous group with a selected sample of persons, the sample being so selected as to lead to as great a degree as possible of pertinent significance in the comparisons made. This has

been the motive in forming the FHR Series in the manner described above. At the same time sound scientific methodology demands that the manner of selection of the comparison group, and the statistical consequences automatically and necessarily entailed by the manner of selection, shall be defined and described with as much detail and candor as possible, so that the reader may at every stage of the report form for himself an intelligent judgment as to the meaning and significance of the comparative results set forth. To such definition and description of the FHR Series (and also of the Long. Series) we now address ourselves in the next three chapters, and Chapter IX.

CHAPTER III

CHARACTERISTICS OF THE COMPARED GROUPS

IN this chapter we shall set forth and discuss certain of the group characteristics of the two series, Longevous and FHR, and especially their age distributions. All of the persons in both Long. and FHR series are *whites*.

The *sex distribution* of the persons in the two series of material is shown in Table 2.

TABLE 2
Sex Distribution of Propositi

	MALES	FEMALES	TOTALS
<i>Long. Series</i>	190	175	365
<i>FHR Series</i>	72	71	143

It is seen that the *propositi* in both series represent each sex about equally. In most of the computations and discussions both sexes will be dealt with together. The numbers are not large enough for profitable discussion separately.

The frequency distributions and biometric constants relative to the *living age* of the *propositi* in the two series are shown in Table 3.

It is evident from the figures in Table 3 that the individuals composing the Long. Series are a highly selected lot, showing little variation, either absolute (standard deviation) or relative (coefficient of variation) in respect of age. Their mean (and median) ages testify in another way to the rigor of the selection represented, since only about four persons in a thousand born alive ever reach the age of 95 years.

The individuals in the FHR Series, on the other hand, are seen to furnish a group that appears to be from certain viewpoints profitably

TABLE 3
*Frequency Distributions and Biometric Constants for
 Age (Living) of Propositi*

AGE IN YEARS	LONG. SERIES	FHR SERIES ⁶
10- 19 .....	...	4
20- 29 .....	...	12
30- 39 .....	...	19
40- 49 .....	...	32
50- 59 .....	...	40
60- 69 .....	...	22
70- 79 .....	...	6
80- 89 .....	...	1
90- 94	173	...
95- 99	133	...
100-104	52	...
105-109	7	...
Totals	365	136
Mean	95.43 ± .13 yrs.	48.75 ± .83 yrs.
Median	94.95 ± .17 yrs.	50.25 ± 1.04 yrs.
Standard deviation	3.79 ± .10 yrs.	14.40 ± .59 yrs.
Coefficient of variation..	3.97 ± .10%	29.53 ± 1.31%

usable for comparison with the longevous. Life tables⁷ give the expectation of life (mean after-lifetime) at birth in 1901 (which appears to be the date most nearly comparable for the present data) for white persons in cities of the Original Registration States, as 47.32 years for males, and 47.90 years for females. These values are not widely different from the mean living age of the propositi in our FHR Series. That series may therefore be taken as a group of persons who had lived, on the average, about the same length of time that people in general live, on the average, after birth.

⁶ With the seven dead propositi omitted, leaving 136 as the number in the distribution from which these constants are computed. The constants for the Long. Series were computed from a distribution with two year class units.

⁷ Glover, J. W. United States Life Tables 1890, 1901, 1910, and 1901-1910. Washington (Bureau of the Census), 1921.

It has been pointed out earlier that there was no selection of the *propositi* in the FHR Series relative to their own living age except such as may have been involved (a) in taking as *propositus* the oldest living individual in each sibship, and (b) in requiring that all six immediate ancestors should be dead, and their ages at death known. Furthermore, it has just been shown that the mean living age of the *propositi* in this series is not greatly different from the expectation of life at birth set down in a fairly comparable U. S. life table. But so simple and rough a test as this is not sufficient. It is necessary before we go on to use the FHR Series to compare with the Long. Series to learn more precisely the effects of procedures (a) and (b) *supra*. To do this it is necessary to get the answers to at least four specific questions, as follows:

1. What are the values of the biometric constants relative to age of the total living population at the 1930 Census?

2. What are the values of the biometric constants relative to age of all the living persons (including the *propositi* themselves) in the 136 sibships from which the *propositi* in the FHR Series were drawn as oldest living individuals?

3. How do the frequency distributions of ages of (α) the *propositi* in the FHR Series, and of (β) all the living individuals in the sibships from which the *propositi* were drawn as oldest individuals compare with the similar distribution of (γ) the total living white population at the 1930 Census?

With the answers to these three questions in hand it will be possible to form a reasonable judgment as to the effect upon the FHR Series of procedure (a) *supra*, that is the taking of the oldest living individual as *propositus*.

It will be necessary then to consider:

4. What will be the frequency distribution and biometric constants of a series of say 200 individuals, each the oldest living in the sibship to which he or she belongs, these sibships being taken at random, and without reference to whether the six immediate ancestors are living or dead, except for the requirements that the ages of all of them shall be recorded and that at least one of them shall be living?

The answer to this question will permit some judgment to be formed as to the effect of procedure (b) *supra*, that is the requirement in making the FHR Series that all six immediate ancestors must be dead.

In answer to questions 1 and 2 Table 4 presents the age data for the living population of the United States.*

TABLE 4
Biometric Constants for Age (Living) of (γ) White Population of United States (1930 Census. Both Sexes); and (β) Total Living Persons in Sibships From Which FHR Series Propositi Were Drawn

	γ	β
	U. S.	FHR Series Total Sibships (living)
Mean	29.864 ± .001 yrs.	45.774 ± .407 yrs.
Median	26.975 ± .002 yrs.	45.638 ± .510 yrs.
Standard deviation	19.942 ± .001 yrs.	13.704 ± .288 yrs.
Coefficient of variation....	66.776 ± .004 %	29.94 ± .68 %
N	108,786,878	517

From Table 4 we note:

The living members of the sibships from which the propositi of the FHR Series were drawn plainly form a selected group differentiated in respect of age from the total living white general population. This selection (and differentiation) is in the same direction as that characterizing the Long. Series, but is less intense (that is, has not proceeded so far in the same direction) than in the Long. Series. The total living sibships have a mean age nearly 16 years higher than that of the living whites of the general population. The median age is over 18 years higher in the total sibling group. The variability of the total living sibships to which the FHR propositi belong, whether measured absolutely (S. D.) or relatively (C. of V.) is significantly less than that of the living white general population. Altogether it appears that, in comparing our Long. Series with the FHR Series, we are making a much less drastic comparison, so far as concerns the age of propositus,

* Fifteenth Census of the United States: 1930. Population, Vol. III, Part 1. Washington (Gov't Printing Office), 1932. Data from p. 14.

than would be the case if we were able to compare the Long. Series with the living general population.

The relations of the basic constants of the four series of data under discussion are shown graphically in Figure 6.

In the order of arrangement as depicted in Figure 6 the mean ages of the four series stand in the ratios 1 : 1.63 : 1.53 : 3.20, and the standard deviations in ages in the ratios 1 : 0.72 : 0.69 : 0.13.

2. The distribution of variation in the four series under discussion may well be exhibited at this point in the discussion. They are shown graphically in Figure 7, on a relative basis, the frequencies being plotted as percentages for 10 year intervals of age.

This Figure 7 shows in graphic form the differences between the several series that have already been deduced from the biometric constants. The greater skewness and variability of the general population is striking. The extreme differentiation of the propositi of the Long. Series from all the others is also made abundantly clear in this diagram.

3. If the final columns of Tables 3 and 4 are compared it is plain that the selection of the oldest living individual in the sibships as propositus in the FHR Series made no serious difference from what the result would have been if all living sibs had been taken. The mean age of the FHR propositi is $2.98 \pm .93$ years higher than that of the total living sibships from which they were drawn. While this difference is slightly more than three times its probable error, and therefore probably significant, it is absolutely so small as to make no practical difference in any conclusions likely to be drawn in such a study as the present one. In variability, as measured by the standard deviations, the value for the FHR propositi is $0.70 \pm .66$ years greater than that for the total living sibships from which they were drawn. This is an obviously insignificant difference, as is also that between the coefficients of variation. But whether the oldest living individual in the sibship be taken or all the living sibs, the FHR Series is markedly differentiated from the general population of living persons. This appears to be primarily a resultant of the fact that the FHR propositi come from *completed* families, in the sense that their parents (being dead) are not going to have any more children. On the other hand, the excess of very young persons in the general living population arises primarily from the fact that a large proportion of them belong to incomplete families (in the same sense).

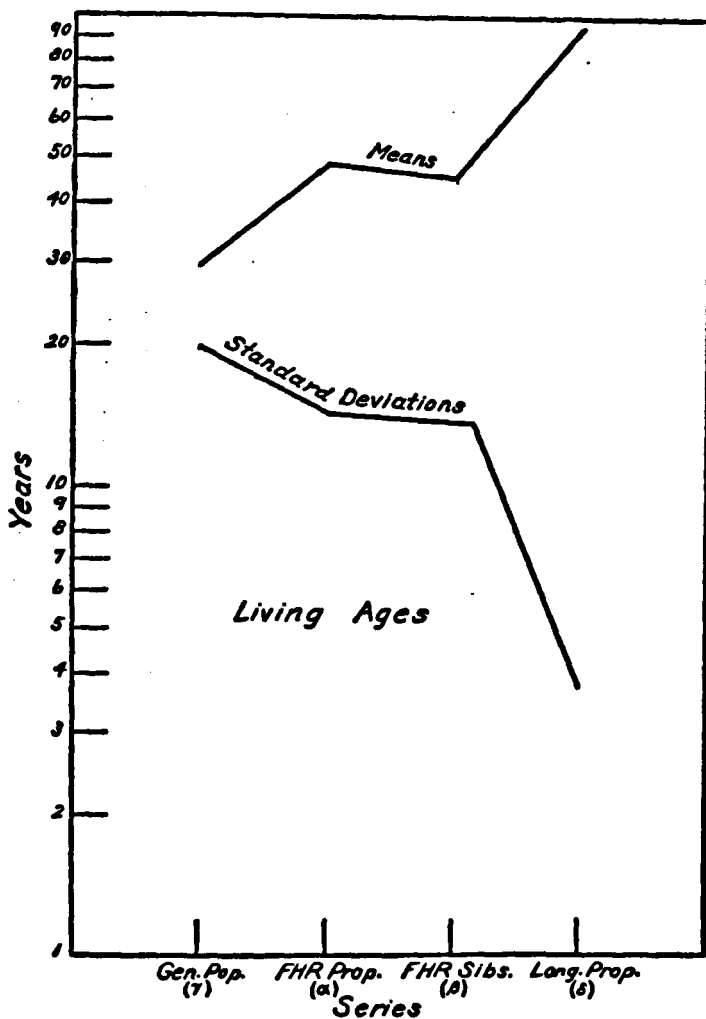


FIG. 6. VALUES OF THE MEANS AND STANDARD DEVIATIONS FOR AGE OF (α) PROPOSITI IN FHR SERIES; (β) ALL LIVING INDIVIDUALS IN SIBSHIPS FROM WHICH PROPOSITI WERE DRAWN; (γ) TOTAL LIVING WHITE POPULATION OF U. S.; (δ) PROPOSITI IN LONG. SERIES

ANCESTRY OF THE LONG-LIVED

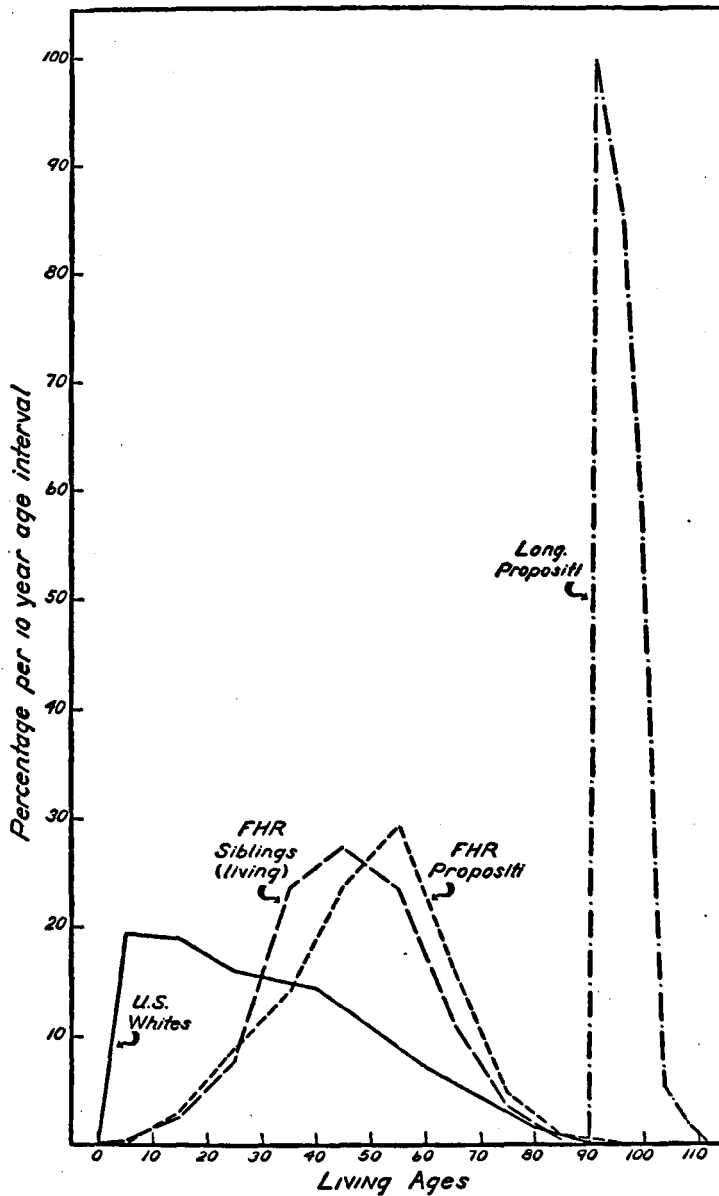


FIG. 7. FREQUENCY POLYGONS OF VARIATION IN AGE OF (a) PROPOSITI IN FHR SERIES (SHORT DASH LINE); (b) ALL LIVING INDIVIDUALS IN SIBSHIPS FROM WHICH PROPOSITI WERE DRAWN (LONG DASH LINE); (c) TOTAL LIVING WHITE POPULATION OF U. S., 1930 (SOLID LINE); (d) PROPOSITI IN LONG. SERIES (DOT-DASH LINE)

We now turn to the consideration of our fourth question *supra*. Table 5 gives the distribution of ages, and the biometric constants computed therefrom, in a sample of 200 individuals taken at random from our Family History Records, under the following rules of sampling: (a) each individual is the oldest living member of the sibship from which it is drawn, and (b) one (any one) or more of his (or her) six immediate ancestors was living at the time of record.

It is at once apparent that the requirement set up for the drawing of our sample of FHR propositi that all six immediate ancestors should be dead—that is that the propositi should belong to completed families—has a marked effect in determining the distribution of their ages. The

TABLE 5

Age of Oldest Living Individual in Random Sample of Sibships in Which One or More of His (or Her) Six Immediate Ancestors (2 Parents, 4 Grandparents) was Living

AGE	FREQUENCY (ABSOLUTE)	FREQUENCY (PER CENT)	ACCUMULATED PERCENTAGES
0- 4	5	2.5	2.5
5- 9	11	5.5	8.0
10-14	13	6.5	14.5
15-19	17	8.5	23.0
20-24	34	17.0	40.0
25-29	37	18.5	58.5
30-34	25	12.5	71.0
35-39	28	14.0	85.0
40-44	14	7.0	92.0
45-49	8	4.0	96.0
50-54	6	3.0	99.0
55-59	2	1.0	100.0
Totals	200	100.0	....
Mean		= 28.03 ± .57 yrs.	
Median		= 27.70 ± .71 yrs.	
Standard deviation		= 11.89 ± .40 yrs.	
Coefficient of variation		= 42.4 ± 1.7 %	

mean age of the FHR propositi is 20.72 ± 1.01 years higher than that of the individuals of Table 5, and the median age is 22.55 ± 1.26 years higher. The individuals of Table 5 are somewhat less variable absolutely (Diff.s.d. = $2.51 \pm .71$ years), but significantly more variable relatively (Diff.c. of v. = 12.9 ± 2.2 per cent) than the FHR propositi.

Taking families not necessarily completed, as is done in Table 5, considerably curtails the age distribution of the oldest living individuals in the offspring sibships at the upper end. None of the individuals is 60 or more years old. Forty per cent of them are under 25 years of age, and nearly 60 per cent are under 30 years.

The close similarity of the constants of Table 5 with those of the first column of Table 4 (the total living white population of the U. S., 1930) is most striking. The means differ by only $1.83 \pm .57$ years; and the medians by only $0.73 \pm .71$ years, the Table 5 sample being higher in the one case and lower in the other. The Table 5 sample is significantly less variable, as might be expected, both from the size of the sample, and much more from the fact that in Table 5 the method of taking the sample excludes all *necessarily* completed families. But the similarity of the centering constants brings out once more the essential normality of our Family History Records in respect of age distribution as compared with the general population. This has been noted before,⁹ but has sometimes been overlooked, denied, or even misrepresented by critics of our work on alcohol and life duration.

There is, finally, another way in which the age characteristics of the two groups studied may be stated. We are comparing two groups of living persons. One of these groups (FHR Series) has an average living age at the time of record of 48.75 years, and consequently from Glover's⁷ life table for both sexes in the Original Registration States as of 1901 has an expectation of life of 22.13 years. It is therefore to be expected that when all the individuals in this group have died their average age at death will turn out to be 70.88 years or thereabouts. The other group of living persons (Long. Series) has an average living age at the time of record of 95.43 years, and an expectation of life of 2.12 years, approximately one-tenth of that of the other group. When this second group is all dead the average age at death of all the individuals in the group will turn out to be about 97.55 years.

⁹ Cf. Pearl, R. *Alcohol and Longevity, passim.*

To summarize this long discussion of the age characteristics of the *propositi* in the material of this study, it may be said that:

1. Detailed data have been presented which enable the reader to understand precisely the nature, in respect of living age of the *propositi*, of the two sets of data (Long. Series and FHR Series) that we propose to discuss.

2. Taking the oldest living individual in the sibship as *propositus* in the FHR Series gives no essentially different result, for practical purposes, than if all living individuals in the sibship had been taken together as a sort of composite *propositus*. Furthermore there is an element of fairness in taking the oldest living individual for comparative purposes because in the Long. Series the *propositus* is always the oldest living member of the sibship to which he (or she) belonged.

3. Because the FHR *propositi* come from necessarily completed families their mean age is higher and their variability in age is lower than is the case in a random sample of all living individuals in the general population. This means that in using them for comparison with the Long. Series we are making a less severe contrast than would be the case if incomplete families were used. But the comparisons actually made in this paper would, on just that account, appear to be all the fairer, because the individuals in the Long. Series come from necessarily completed families (both parents being long since dead).

CHAPTER IV

THE EFFECT OF CERTAIN TYPES OF SELECTION OF THE IMMEDIATE ANCESTRY ON THE AGE CHARACTERISTICS OF THE PROGENY

IN CHAPTER III we have discussed the question of the effect of the method of forming the FHR Series upon the age distribution of the *propositi* in that series. It was there concluded that while *a priori* it would be expected that the requirement that all six immediate ancestors must be dead might tend, in a sample not directly selected relative to the age of the living progeny as was the Long. Series, to result in some preponderance of relatively young ancestors, and consequently relatively young *propositi* whether dead or living, nevertheless the actual FHR Series *propositi* turned out to have a mean living age not much different from the mean duration of life (expectation of life at birth) from the life table. It was pointed out, however, that the matter required more extended investigation. To this we now turn.

From our *Family History Records* there have been extracted a series of distributions of the ages (age at the time of record for the living and age at death for the dead) of the individuals in sibships, according to the following rules of selection:

1. Each sibship must include both living and dead individuals.
2. Each such sibship must of necessity fall into, and was in fact properly placed in, one or another of the following categories relative to its six immediate ancestors:
 - a. All six immediate ancestors dead, none living. (These are the sibships to which the *propositi* in the FHR Series belong.)
 - b. Any five immediate ancestors dead, one living.
 - c. Any four immediate ancestors dead, two living.
 - d. Any three immediate ancestors, dead, three living.
 - e. Any two immediate ancestors dead, four living.
 - f. Any one immediate ancestor dead, five living.
 - g. No immediate ancestor dead, all six living.

The original intention was to get 200 sibships under each category *a* to *g* inclusive. This was done in the case of categories *b* and *c*, but proved to be impossible for any of the others. Extensive as our Family History Records are the strain put upon them by the dual requirements set forth above was too great, especially when it is remembered that we also required that the ages of the six immediate ancestors be known and recorded. The numbers of sibships obtained in the several categories were 136 in category *a*; 200 each in categories *b* and *c*; 136 in category *d*; 67 in *e*; 43 in *f*; and 8 in *g*. The decline in numbers with increasing numbers of living ancestors above two is what would be expected from general experience. But few persons, and those few young, have both parents and all four grandparents alive. The present writers come from fairly long-lived stocks; but in the cases of both of them one grandparent was dead before they were born. This is by no means an unusual experience.

However, in each case except categories *b* and *c* every single sibship in the Family History Records of the Department of Biology fulfilling the requirements was used, without any other selection whatsoever. In the case of categories *b* and *c* the first 200 sibships fulfilling the requirements were taken in order as they stood in the original records books, so that again the sampling was random within the rules laid down.

For each of these sibships the biometric constants for age were computed, under the following four heads:

- a.* Oldest living sib in the sibship.
- β.* Oldest dead sib in the sibship.
- γ.* All living sibs in the sibship.
- δ.* All dead sibs in the sibship.

The values so obtained are exhibited in Tables 5a-5d inclusive. So far as we are aware these figures represent the first systematic attempt to analyze the age constitution of a family of children in relation to the vital status of their ancestry. The analysis could, of course, be carried much farther, and doubtless will be as biostatisticians become more generally interested in the genetic aspects of their problems. But for our present purposes it does not seem necessary to carry the matter further than is done here.

TABLE 5a
*Biometric Constants for Age of Oldest Living Sib in Sibships of Seven Different Specified
 Types of Ancestry*

TYPE OF ANCESTRY	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
All six immediate ancestors dead, none living.....	48.75±0.83	50.25±1.04	14.40± .59	29.5±1.3
Any five immediate ancestors dead, one living.....	39.25± .49	39.70± .61	10.23± .34	26.0± .9
Any four immediate ancestors dead, two living.....	30.20± .53	29.84± .66	11.09± .37	36.7±1.4
Any three immediate ancestors dead, three living.....	22.50± .53	22.50± .66	9.14± .37	40.6±1.9
Any two immediate ancestors dead, four living.....	16.19± .63	15.69± .79	7.63± .44	47.1±3.3
Any one immediate ancestor dead, five living.....	14.07± .73	14.05± .91	7.09± .52	50.4±4.5
No immediate ancestors dead, all six living.....	11.25±1.15	12.00±1.44	4.84± .82	43.0±8.5

TABLE 5b

Biometric Constants for Age of Oldest Dead Sib in Sibships of Seven Different Specified Types of Ancestry

TYPE OF ANCESTRY	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
All six immediate ancestors dead, none living.....	32.26±1.08	31.52±1.35	17.28±0.76	53.6± 3.0
Any five immediate ancestors dead, one living.....	23.04± .77	22.67± .97	16.14± .54	70.0± 3.3
Any four immediate ancestors dead, two living.....	12.34± .64	5.45± .80	13.33± .45	108.0± 6.7
Any three immediate ancestors dead, three living.....	7.60± .62	2.46± .78	10.67± .44	140.4±12.8
Any two immediate ancestors dead, four living.....	3.58± .53	2.10± .66	6.43± .37	179.9±28.7
Any one immediate ancestor dead, five living.....	3.21± .47	2.03± .59	4.53± .33	141.4±23.0
No immediate ancestors dead, all six living.....	1.31± .28	1.17± .35	1.18± .20	90.1±24.6

PROGENY AGE

TABLE 5c

Biometric Constants for Age of All Living Sibs in Sibships of Seven Different Specified Types of Ancestry

TYPE OF ANCESTRY	N	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
All six immediate ancestors dead, none living..	517	45.77±0.41	45.64±0.51	13.70±0.29	29.9±0.7
Any five immediate ancestors dead, one living..	846	33.75± .26	34.03± .33	11.07± .18	32.8± .6
Any four immediate ancestors dead, two living..	919	24.03± .25	23.72± .31	11.28± .18	46.9± .9
Any three immediate ancestors dead, three living	576	17.47± .27	16.53± .34	9.66± .19	55.3±1.4
Any two immediate ancestors dead, four living	287	13.05± .30	11.30± .38	7.63± .21	58.5±2.1
Any one immediate ancestor dead, five living...	164	11.77± .36	11.16± .45	6.89± .26	58.6±2.8
No immediate ancestors dead, all six living....	23	7.61± .62	6.76± .78	4.39± .44	57.7±7.4

TABLE 5d

*Biometric Constants for Age of All Dead Sibs in Sibships of Seven Different Specified
Types of Ancestry*

TYPE OF ANCESTRY	N	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
All six immediate ancestors dead, none living...	389	17.89±0.64	11.71±0.80	18.65±0.45	104.2± 4.5
Any five immediate ancestors dead, one living..	485	15.26± .47	10.63± .59	15.44± .33	101.2± 3.8
Any four immediate ancestors dead, two living..	479	8.22± .35	3.58± .44	11.25± .25	137.0± 6.5
Any three immediate ancestors dead, three living	259	5.06± .36	2.52± .45	8.61± .26	170.1±13.1
Any two immediate ancestors dead, four living..	114	2.73± .32	1.85± .40	5.03± .22	184.5±20.8
Any one immediate ancestor dead, five living...	67	2.58± .31	1.92± .39	3.73± .22	144.7±19.2
No immediate ancestors dead, all six living.....	10	1.18± .24	1.17± .30	1.13± .17	95.8±32.1

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Keeping always in mind the magnitude of the samples upon which several items are based, the data of Tables 5a-5d permit certain generalizations to be reached relative to the present material. These are probably true generally, but must await confirmation from the study of other family statistics.

1. It appears that the mean age of offspring, whether living or dead, or whether they are the oldest individuals of the sibships to which they belong or all siblings, *decreases* in an orderly manner as the number of their six immediate ancestors still living increases. The oldest offspring, on the average, living or dead, belong to sibships where all six immediate ancestors are dead at the time of record. It is thus evident that the propositi in the FHR Series in this book constitute a group of the greatest average living age possible to obtain from family statistics selected primarily upon the basis of ancestry alone, so far as may be judged from this material. Therefore the FHR Series propositi constitute a fair group in this respect as well as in others for comparison with the longevous group. The Long. Series propositi are all living individuals at the time of record. It is plainly only fair to take living individuals to compare with them. The six immediate ancestors of the propositi in the Long. Series are necessarily dead. Those of the comparison group must in fairness also be dead. But Tables 5a and 5c show also that *if any other specification whatever is made relative to the vital status of the ancestors* (such, for example, as that the selection should be only of the offspring sibships containing both living and dead, without any attention whatever to the ancestry) the result would be offspring sibships of lower average age than those selected from the same universe in the way those to which the FHR Series propositi belong were selected. And the oldest living individuals in such sibships will be of lower average age than in sibships selected as were those of our FHR Series. So that by selecting the FHR Series propositi for a comparison group in the way we have, the differences between Long. and FHR Series have been minimized so far as it is possible to minimize them and still adhere scrupulously to uniform and consistent rules of selection of the sample.

2. As the number of living ancestors (among the six immediate ancestors) increases the mean age of the offspring sibs declines in an orderly manner, such that for each category of sibs investigated there is an equal proportional decrement in mean age for each additional

living immediate ancestor. That is to say the mean age of offspring in each category when plotted on an arithlog grid, with number of living immediate ancestors from 0 to 6 as abscissa, fall very closely upon a straight line sloping downward from left to right as shown in Fig. A.

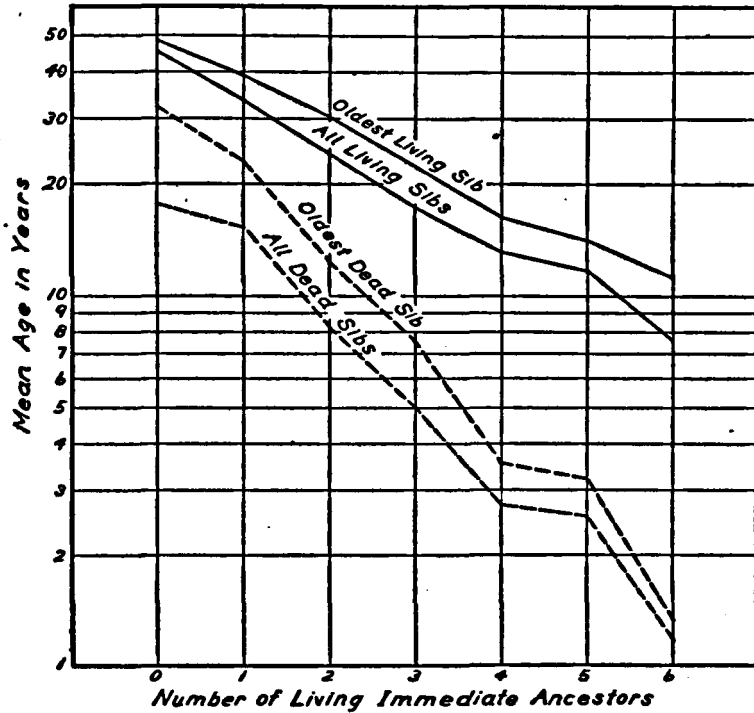


FIG. A. DECREASE OF MEAN AGE IN FOUR CATEGORIES OF OFFSPRING SIBS WITH INCREASING NUMBER OF LIVING IMMEDIATE ANCESTORS

The slopes of the lines are different in each of the four categories of offspring sibs. In the case of *oldest living sibs* the line has a slope of roughly 21.5 per cent. In the case of *all living sibs* the slope is about 25.5 per cent. The slopes for the dead sibs are plainly much steeper. That for the *oldest dead sib* is about 39.3 per cent, and that for *all dead sibs* roughly 42.4 per cent.

This rule of equal proportional decrements in mean age of offspring with numbers of living immediate ancestors is, so far as we know, an entirely novel and hitherto unsuspected result. A reasonable biological

explanation of its occurrence would seem tentatively to be that it fundamentally rests upon two circumstances; namely, first, that the birth interval in man (length of time between two successive pregnancies) is a figure of moderate absolute variability—or put the other way around, in a reasonably constant figure, and, second, that the incidence of mortality within an offspring sibship is fairly random relative to the birth order of the offspring. But plainly whatever the explanation of the phenomenon, its regular and orderly character is impressive, particularly when it appears in such relatively small samples, statistically speaking, as those here dealt with.

3. Generally speaking the mean and median ages of living sibs (whether oldest living sib or all living sibs) are not significantly different from each other, indicating substantial symmetry of the distribution. The age distribution for the dead sibs, on the other hand, are markedly skew—indeed in most cases J-shaped—and in consequence there are systematic and considerable differences between the means and medians.

4. The absolute variation in offspring ages measured by the standard deviation tends to decrease, as would be expected, in passing from 0 to 6 living immediate ancestors. But the mean ages decrease even more markedly, so that in consequence the relative variation, as measured by the coefficient of variation, tends to increase with the number of immediate ancestors.

CHAPTER V

BIRTHPLACE, RACE STOCKS, AND ALCOHOLIC HABITS OF THE GROUP OF NONAGENARIANS AND CENTENARIANS



WHILE the primary interest of the present study centers around the inheritance factor or element in longevity, still we must know something of the geographical and racial origins of the persons in the Longevous Series. And also since nonagenarians and centenarians are, by the very fact of their existence, such rare biological specimens it will be of interest to examine briefly into their habits relative to the use of alcoholic beverages. There are those who believe, or at least profess to believe, that any such usage is absolutely incompatible with the achievement of great longevity. We shall see in this chapter what one sample, at least, of extremely longevous persons has to offer in the way of evidence on this point.

Table 6 presents data regarding the birthplace (from which some judgment as to race stock may be formed) and habits relative to the use of alcohol by the persons in the Long. Series (nonagenarians and centenarians). Data on these points for the material from which the FHR Series is drawn have already been given elsewhere¹⁹ and need not be repeated here.

The classification of the individuals in Table 6 relative to their usage of alcohol as a beverage is based upon the *maximum* used at any period of their lives. This seems as reasonable a basis as any for a general exhibition of the characteristics of the material. While the drinking habits of individuals may change in the course of such long lives, it will be useful to see what was the maximum of potatory performance achieved by each individual.

The data of Table 6 as to birthplace are shown graphically in Figure 8.

From Table 6 and Figure 8 the following points may be noted:

1. In this group of nonagenarians and centenarians 88.3 per cent were native-born, and 11.7 per cent foreign-born. In the United

¹⁹ Pearl, R. Alcohol and Longevity, *passim*.

TABLE 6

Birthplace and Habits Relative to Alcohol of Persons in the Long Series (Nonagenarians and Centenarians)

PLACE OF BIRTH	ABSTAINERS		VERY MODERATE		MODERATE		HEAVY		VERY HEAVY		TOTALS		Both sexes	Per cent
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
<i>Native Born</i>														
New York	14	24	3	3	7	1	2	..	..	..	26	28	54	14.9
Massachusetts	8	24	8	5	8	..	..	..	..	..	24	29	53	14.6
Pennsylvania	8	10	5	5	3	1	..	..	..	..	16	16	32	8.8
Ohio	9	11	3	3	4	1	..	..	..	..	16	15	31	8.6
Maine	5	7	4	4	2	1	..	..	..	..	11	12	23	6.4
Connecticut	6	5	4	2	1	..	..	..	..	..	11	7	18	5.0
Virginia	2	7	1	1	3	1	..	..	..	..	6	9	15	4.1
New Hampshire	4	2	1	6	1	..	..	..	..	..	6	8	14	3.9
Vermont	3	6	1	1	1	..	..	..	..	..	5	7	12	3.3
New Jersey	4	3	1	2	1	..	..	..	..	..	6	5	11	3.0
North Carolina	1	4	2	..	1	1	..	..	1	..	5	5	10	2.8
Indiana	6	2	..	..	..	2	..	..	..	..	6	4	10	2.8
Maryland .....	..	2	2	..	2	1	..	..	..	..	4	3	7	1.9
South Carolina	2	1	..	..	..	1	1	..	..	..	3	2	5	1.4
Illinois	1	..	3	1	..	..	..	..	..	..	4	1	5	1.4
Georgia .....	..	..	2	..	2	..	..	..	..	..	4	..	4	1.1
Rhode Island	1	..	..	1	1	..	..	..	..	..	2	1	3	0.8
Kentucky .....	..	..	2	..	1	..	..	..	..	..	3	..	3	.8
Tennessee	1	..	..	..	..	..	..	..	1	..	2	..	2	.6
Michigan	1	..	..	..	1	..	..	..	..	..	2	..	2	.6
Delaware .....	..	..	..	1	1	..	..	..	..	..	1	1	2	.6
Alabama .....	..	..	1	..	..	..	..	..	..	..	1	..	1	.3
Missouri	1	..	..	..	..	..	..	..	..	..	1	..	1	.3
Florida	1	..	..	..	..	..	..	..	..	..	1	..	1	.3

TABLE 6—Continued

PLACE OF BIRTH	ABSTAINERS		VERY MODERATE		MODERATE		HEAVY		VERY HEAVY		TOTALS		Both sexes	Per cent
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀		
<i>Foreign Born</i>														
Ireland	3	2	..	1	1	..	..	..	..	..	4	3	7	1.9
Germany	1	..	..	..	4	1	..	..	..	..	5	1	6	1.7
England .....	..	2	1	2	1	..	..	..	..	..	2	4	6	1.7
Norway	1	2	..	1	1	..	..	..	..	..	2	3	5	1.4
Canada .....	..	1	..	..	2	..	1	..	1	..	4	1	5	1.4
Scotland	1	1	..	1	..	..	..	..	..	..	1	2	3	0.8
Holland .....	..	2	..	..	1	..	..	..	..	..	1	2	3	.8
Nova Scotia .....	..	1	1	..	..	..	..	..	..	..	1	1	2	.6
Wales .....	..	1	..	..	..	..	..	..	..	..	..	1	1	.3
Russia	1	..	..	..	..	..	..	..	..	..	1	..	1	.3
Italy .....	..	..	..	..	1	..	..	..	..	..	1	..	1	.3
Finland .....	..	..	1	..	..	..	..	..	..	..	1	..	1	.3
Belgium .....	..	..	..	..	..	1	..	..	..	..	..	1	1	.3
Panama .....	..	..	1	..	..	..	..	..	..	..	1	..	1	.3
Totals	85	120	47	40	51	12	4	..	3	..	190	172	362*	100.4
Percentages by sex as to alcohol	44.7	69.8	24.7	23.3	26.8	7.0	2.1	..	1.6	..	99.9	100.1		
Group totals	205		87		63		4		3		362			
Group percentages	56.6		24.0		17.4		1.1		0.8		99.9			

* Three cases are missing because there was no information given regarding the use of alcohol. These are Cases Nos. 607, 1630, and 2200.

ANCESTRY OF THE LONG-LIVED

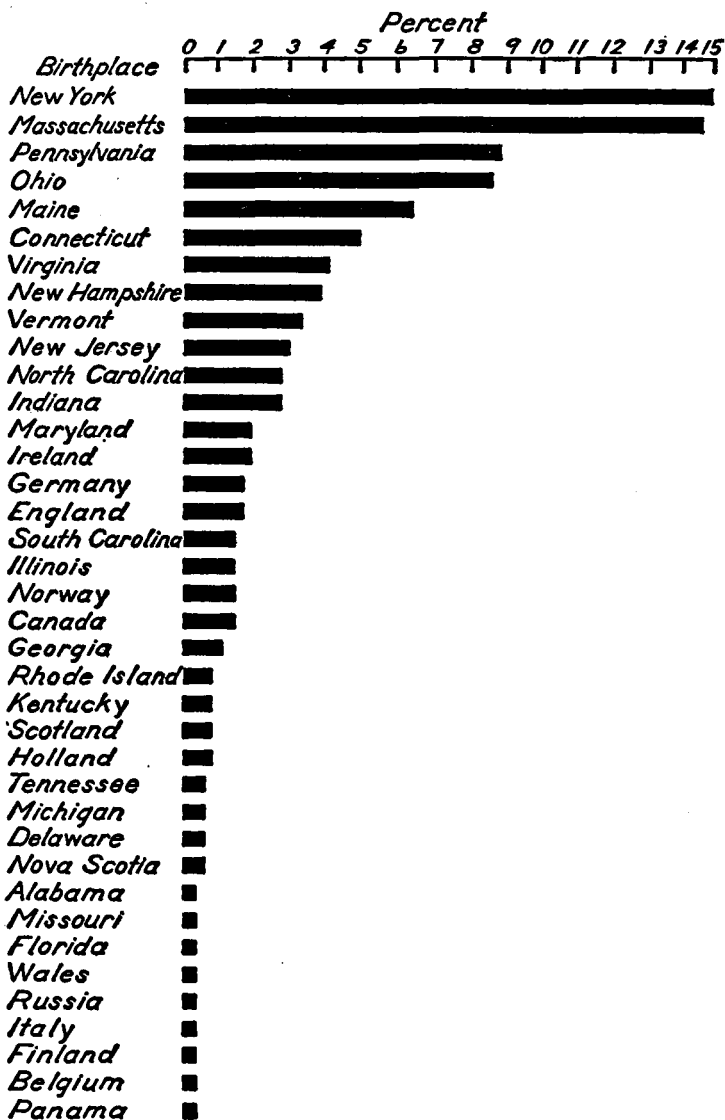


FIG. 8. BAR DIAGRAM SHOWING THE BIRTHPLACE OF 362 LIVING NONAGENARIANS AND CENTENARIANS. THE LENGTHS OF THE BARS ARE PROPORTIONAL TO THE NUMBER BORN IN EACH PLACE.

States as a whole in 1930 the proportions of the white population were 87.7 per cent native-born, and 12.3 per cent foreign-born. It thus appears that these living nonagenarians and centenarians have grossly about the same distribution as to nativity as does the whole living white population at the present time. But let us examine into the matter a little further. The following figures show the approximate percentages of foreign-born in the total white population at the census enumerations from 1850 on.

It is evident that the close approach of the foreign-born percentages of the Long. Series is somewhat fortuitous. If immigration restrictions had not operated in recent years to reduce the percentages of foreign-born in the population it would not have been so close as it is. But in 1850, roughly about the time when most of the foreign-born in the Long. Series came to this country, the proportion of foreign-born in the white

TABLE 7

Percentages of Native-born and Foreign-born in the White Population of the United States

CENSUS	NATIVE-BORN	FOREIGN-BORN
1850 ¹¹	88.5	11.5
1860	84.6	15.4
1870	83.4	16.6
1880	84.6	15.4
1890	83.2	16.8
1900	84.5	15.5
1910 ¹²	83.7	16.3
1920 ¹³	85.9	14.1
1930	87.7	12.3

¹¹ Figures for 1850-1900 inclusive computed from data given in Tables 17 and 54 of reference cited in footnote 16 *infra*. The percentages given reckon all foreign-born as whites. This is not strictly true, but the error is insignificant.

¹² Computed from data given in Table 17 of the reference cited in footnote 8 *supra*.

¹³ Figures for 1920 and 1930 from Table 3 of the reference cited in footnote 8 *supra*.

population was almost exactly the same as that shown by the Long Series.

2. Just under 30 per cent of the persons in the Long Series were born in one or the other of the two states, New York and Massachusetts. Fourteen states (Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida) bordering on the Atlantic seaboard furnished (as birthplace) 60.8 per cent of the total. If Pennsylvania be added to this group, as a seaboard state for all practical purposes, the percentage rises to 69.6. If the reckoning is based upon the native-born portion of the whole group it appears that 68.8 per cent of the sample of nonagenarians and centenarians was born in one or another of the fourteen states lying along the Atlantic seaboard, in the strict sense of the term. If Pennsylvania be included the percentage becomes 78.8. Only one person in the group was born west of the Mississippi River. Only 14.2 per cent of the whole group (native and foreign together) was born south of the Mason and Dixon line. Altogether it is plain that this group of extremely longevous persons now (at the time of record) living originated preponderantly from the northeastern part of the country. If we take as the northeastern part of the country the nine states east of Ohio and north of the Mason and Dixon line it appears that 60.7 per cent of our whole longevous group, and 68.8 per cent of the native-born portion of it, were born in that region. Now these persons were born around a hundred years ago. In 1830 these nine northeastern states contained 51.4 per cent of the total white population of the country. So it is seen that this portion of the country is even more heavily represented in the Long Series (as birthplace) than its relative population would warrant. This is in part due to the fact that, because of the better early vital records of that part of the country, it has been easier for cases originating there to satisfy the critical requirements for admission into our collection of longevity material.

3. Turning now to the foreign-born portion of this group of nonagenarians and centenarians it comes as something of a surprise to find that the Irish born constitute the largest single national group as to

birthplace. The Irish are known to be a rather short-lived people, taken as a group.¹⁴ Germany and England each contribute (as to birthplace) practically the same number as Ireland to this sample of the longevous. Each of these countries has a larger representation than either South Carolina, Illinois, Georgia, Rhode Island, Kentucky, Tennessee, Michigan, Delaware, Alabama, Missouri or Florida. In the total white population of the country in 1930, 0.85 per cent were born in Ireland, 1.48 per cent in Germany, and 0.74 per cent in England.¹⁵ From these figures it appears that while nonagenarians and centenarians of German birth in this material are present in not far from the same proportion as Germans in the 1930 population, the Irish and English are over-represented in this sample of longevous persons, as compared with the general population of the present time. Unfortunately data are not available as to the country of birth of the foreign-born in 1830. Such information was first included in the census returns of 1850.¹⁶ But in 1850, when the persons of the Long. Series were, generally speaking, in their teens, the proportions of persons of English, Irish, and German birth in the population were as follows:

TABLE 8
Population in 1850

COUNTRY OF BIRTH	NUMBER	PER CENT OF TOTAL WHITES
Ireland	961,719	4.92
Germany	583,774	2.99
England	278,675	1.43

In 1850 there were absolutely more Irish-born persons in the population of the United States—38,077 more to be exact—than there were in 1930, although the total white population was 5.6 times greater in 1930 than it was in 1850. So it is perhaps not remarkable that there are more Irish than any other foreign-born in the Long. Series—there

¹⁴ Dublin, L. I., and G. W. Baker. The mortality of race stocks in Pennsylvania and New York. *Quart. Publ. Amer. Stat. Assoc.*, March, 1920.

¹⁵ See footnote 8 *supra* for source of data. Pp. 7 and 11.

¹⁶ Rossiter, W. S. A Century of Population Growth from the First Census of the United States to the Twelfth 1790-1900. *Washington* (Gov't Printing Office), 1909. Pp. x + 303.

were many more Irish in the country when they started life than there were of foreign-born of any other single nationality.

4. Taking the group as a whole, males and females together, a few more than a half (56.6 per cent) of these nonagenarians and centenarians have been total abstainers from alcohol throughout their long lives. This, however, is not true of the males taken by themselves, where but 44.7 per cent fall in the total abstainer class. Among the women nearly 70 per cent (69.8) are abstainers. At the other extreme 3.7 per cent of the males have been heavy or very heavy drinkers at some time in their lives. More than a quarter of the men have been moderate drinkers, mostly throughout their lives. Seven per cent of the women also fall in this class. Altogether these data furnish cogent evidence that the moderate use of alcoholic beverages does not prevent the attainment of great longevity to the user. They further show that some individuals may indulge heavily in alcohol and still become nonagenarians. These observations are incompatible with the widely preached doctrine that any indulgence in alcohol, however slight, inevitably and universally shortens life.

5. The proportion of abstainers in the Long. Series is somewhat larger than that in a sample of the population of Baltimore, previously studied.¹⁷ That sample gave, taking males and females together, a total abstainer percentage of 45.3. The difference between these two percentages (56.6—45.3) is 11.3. Is this difference greater than might reasonably appear solely as the result of fluctuations of random sampling? If the two groups are thrown together the percentage of abstainers is 46.0. If this were the true proportion of abstainers in the general population the probable error for the difference between percentages in such samples as the actual ones would be

$$.67449 \sqrt{46 \times 54} \sqrt{\frac{1}{5248} + \frac{1}{362}} = 1.83$$

We must therefore conclude that the 11.6 per cent more abstainers in the Long. Series represents a significant difference.

6. The "moderate" and "very moderate" classes of the Long. Series together include 41.4 per cent of the total. This compares with the 37.3

¹⁷ See footnote 10 *supra*.

per cent of moderate drinkers in the Family History Records sample cited above, since in the former study "moderates" included the two classes here separated. The difference here is 4.1 ± 1.78 per cent, the probable error of the difference being computed as before. This difference cannot be regarded as significant, being only a little more than twice its probable error. So then we conclude that while this group of nonagenarians and centenarians included a higher proportion—slightly over 4 per cent higher—of moderate drinkers than a sample of the general population unselected and undifferentiated in respect of longevity from the average run of the American population, this higher proportion is not greater than might arise from fluctuations of sampling. The odds against its having so arisen are over 7 to 1, but such odds do not constitute certainty.

7. The 3.7 per cent of "heavy" and "very heavy" drinkers amongst the males in the Long. Series compares with 27.4 per cent in the sample of the general population. Here the difference is large and obviously significant.

8. Summarizing the whole situation relative to drinking habits we see that this group of nonagenarians and centenarians includes proportionately somewhat more abstainers and more moderate drinkers than a random sample of the general population of average longevity. It therefore necessarily has fewer heavy drinkers. This result confirms, from an independent source, the general conclusion reached in our earlier study of the influence of alcohol upon longevity, to the effect that while moderate drinking could not be shown to affect adversely the duration of life, heavy drinking was statistically associated with curtailed average longevity. But in that study, just as in this, some heavy drinkers achieved longevity far above the average.

CHAPTER VI

VARIATION IN TIAL



HAVING now set forth in considerable detail the general characteristics of our material, we may begin the examination and discussion of the results it yields relative to our primary problem.

The frequency distributions, both absolute and relative, of TIAL in the two series are given in Table 9.

From Table 9 several points of interest are immediately evident. In the first place it is plain that the natural range of variation in TIAL is

TABLE 9
TIAL Distributions

TIAL (in years)	LONG. SERIES		FHR SERIES	
	Absolute	Percentage	Absolute	Percentage
250-269	1	.27	..	...
270-289 .....	..	...	3	2.10
290-309	1	.27	6	4.20
310-329	4	1.10	8	5.59
330-349	5	1.37	14	9.79
350-369	11	3.01	25	17.48
370-389	19	5.21	25	17.48
390-409	34	9.32	15	10.49
410-429	49	13.42	18	12.59
430-449	50	13.70	16	11.19
450-469	81	22.19	10	6.99
470-489	53	14.52	2	1.40
490-509	32	8.77	1	.70
510-529	19	5.21	..	...
530-549	3	.82	..	...
550-569	1	.27	..	...
570-589	1	.27	..	...
590-609	1	.27	..	...
Totals	365	99.99	143	100.00

CASE No. P-188 TIAL=254 YEARS

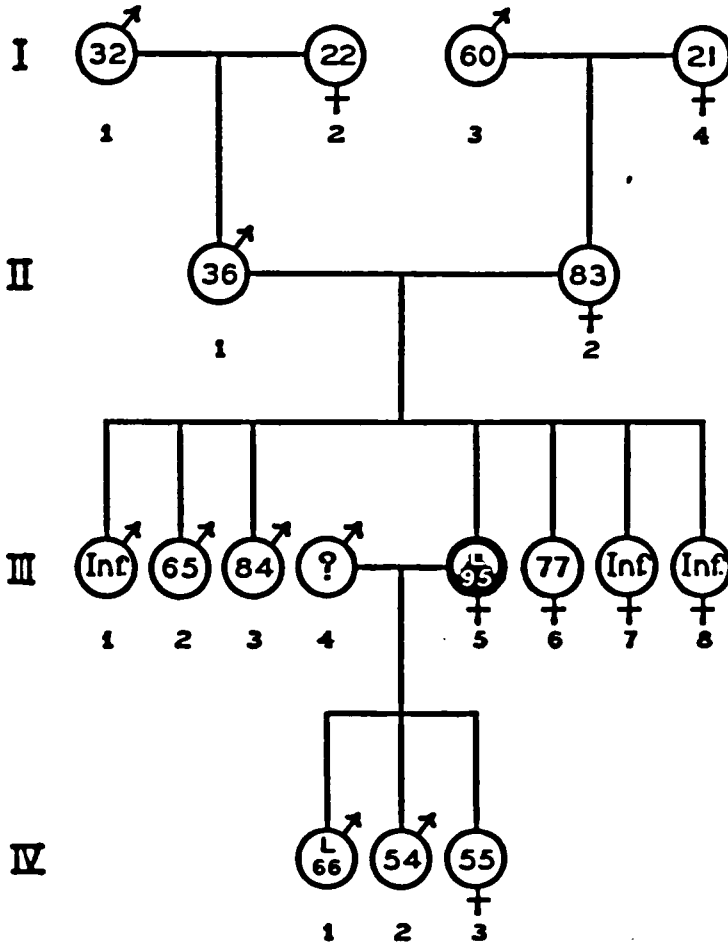


FIG. 9. PEDIGREE OF INDIVIDUAL HAVING LOWEST OBSERVED TIAL.

In this and the following pedigree the propositus is indicated by a solid sex sign. Figures within the circles of the sex signs indicate ages at death in years, except where there is an L above the age figure, which means that the person was living at the time of record, and at the indicated age in years. In this case the propositus was living at age 95, the only survivor of a sibship of seven, three of whom died in infancy (III, 1, 7 and 8). Only one brother (III, 3) achieved anything especially remark-

great. Taking the extreme limits of the age classes it amounts to 359 years (609—250). Actually the lowest observed figure was 254 years, and the highest 599 years. Thus while the lowest observed figure is still more than 150 years greater than the physiological lower limit, the highest observed TIAL falls only one year short of the 600 years which measures the situation where each and every one of a person's six immediate ancestors live to be 100 years old. The pedigrees of the two individuals having the extreme values of TIAL are shown in Figures 9 and 10.

The range of variation in TIAL is *greater*, by about 120 years, in the Long. Series than in the FHR Series, although, as will presently appear and would be expected theoretically, the variation as measured by standard deviation and coefficient of variation is somewhat greater in

TABLE 10
Biometric Constants of the TIAL Distributions in Table 9

CONSTANT	LONG. SERIES	FHR SERIES
Mean	446.14 ± 1.66 yrs.	385.45 ± 2.65 yrs.
Median (from observation)	452.10 ± 2.08 yrs.	382.40 ± 3.32 yrs.
Mode	454.18 ± 2.03 yrs.	Same as mean
Standard deviation	46.88 ± 1.17 yrs.	47.02 ± 1.88 yrs.
Coefficient of variation....	10.52 ± .26%	12.20 ± .49%
μ_2	5.4948	5.5270
μ_3	— 5.2736	— .4515
μ_4	113.6927	75.0338
β_1 .....	.1755	.0012
β_2	3.7814	2.4563
Skewness	— .173 ± .043	...
Curve Type	IV	II

able in longevity, although a sister (III, 6) died only three years short of 80. Two of the three children of the propositus died in their fifties. Of the six immediate ancestors of the propositus only two (I, 3, and II, 2) lived past fifty, and only one, her mother (II, 2) could be regarded as really longevous. The causes of death of the ancestors were as follows: II, 1, smallpox; II, 2, "senility," that is to say, cause of death unknown; I, 1, "fever"; I, 2, in childbirth; I, 3, "rheumatism"; I, 4, pulmonary tuberculosis following childbirth.

CASE No. G-1255 TIAL=599 YEARS

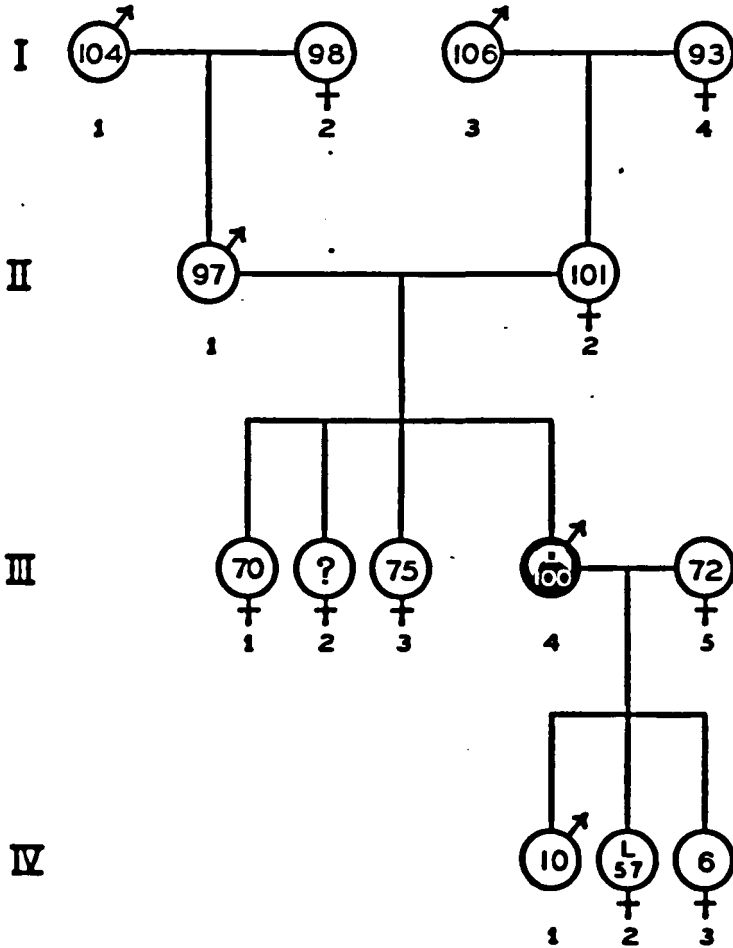


FIG. 10. PEDIGREE OF INDIVIDUAL HAVING HIGHEST OBSERVED TIAL.

In this case the propositus (III, 4), living at the age of 100, was a Scottish seafaring man, who married and "settled down" at the age of 39. His immediate ancestry is very remarkable in point of longevity. His father (II, 1) and his paternal grandmother (I, 2) died as the result of accidents. The causes of death of his other immediate ancestors are unknown. The two children (IV, 1 and IV, 3) died of drowning.

the FHR Series. In both series of observations the highest observed TIAL is well over twice as large as the lowest observed. In other words the summed duration of life of one person's parents and grandparents taken together may well be more than double that of another person, whether the person is a nonagenarian or only just mediocre in respect of his own attained longevity.

The distributions of Table 9 have been fitted, by the method of moments, with Pearsonian frequency curves. The constants are given in Table 10.

The histograms and fitted curves of the two distributions are shown in Figure 11. In this diagram relative (percentage) frequencies are plotted. The equations for the fitted curves are:

$$\text{Long. Series} \quad y = 6.8802 \left(1 + \frac{x^2}{86.4231} \right)^{-11.4398} e^{-10.8301 \tan^{-1} \frac{x}{9.2964}}$$

Origin at 538.1285 years

$$\text{FHR Series} \quad y = 22.163 \left(1 - \frac{x^2}{49.9374} \right)^{8.0176}$$

Origin at mean

In these equations y denotes absolute frequency and x denotes years.

Figure 11 makes plain the great difference in the TIAL distribution in the two series. By no chance could they be looked upon as random samples from a single population in respect of TIAL.

The difference between the two series is shown graphically in another way in Figure 12. In that diagram the two fitted curves of Figure 11 are plotted in the cumulated, or so-called integral form, showing the TIAL values possessed by successive rising percentages of the individuals in each series. Thus the 10 per cent of the FHR Series having the lowest TIAL values show TIALs below 318 years, roughly, as contrasted with 383 years, roughly, for the 10 per cent of the Long. Series with the poorest ancestral longevity. The heavy horizontal lines between the curves at each 10 per cent level show, when read against the abscissal axis, the number of years by which the TIAL of the indicated percentage of the Long. Series exceeds that for the same percentage of the FHR Series.

From the data so far presented it appears that the mean TIAL for the group of nonagenarians and centenarians is 60.69 ± 3.13 years, or

15.75 per cent *greater* than for the FHR Series not directly selected relative to age. The difference is 19.3 times its probable error, and therefore far greater than could reasonably be expected to arise by a chance fluctuation of sampling. It amounts to something more than one average lifetime. At first sight it may perhaps seem puzzling that the difference between the TIALS of the two series is not even greater, considering the stringent selection implied in the low frequency of nonagenarians in the living population. It must, however, be remembered that the *propositus* in the FHR Series is living, in each case except 7 out of the 143. In these 7 cases there were no living members of the offspring sibship from which the *propositus* had to be taken, so the sibling dead at the highest age played the rôle of *propositus*. Since the *propositi* in the FHR Series were persons living at the time of record it follows that they went on living thereafter, and some fraction of them may reasonably be expected to be by way of becoming nonagenarians with the passage of time.

In the Long. Series one-half of the individuals have TIALs of less than 452.1 years, and one-half have TIALs greater than that figure. The corresponding figure for the FHR Series, 382.4 years, is 69.7 ± 3.9 years lower—considerably more than an average life time, and 17.9 times its probable error. It must, however, always be remembered that some part of this difference may be accounted for by the fact that the manner of formation of the FHR Series automatically tends to lower the TIAL values. This effect will chiefly apply to the parents of the *propositi*, and only slightly (and probably insignificantly) to the grandparents.

The most frequently occurring (modal) TIAL is 68.73 ± 3.33 years, or 17.8 per cent higher in the Long. Series than in the FHR Series.

The absolute variability of TIAL, as measured by the standard deviation, is insignificantly greater (0.14 ± 2.21 years) in the FHR Series than in the Long. Series. The difference in relative variability as measured by the coefficient of variation is, however, somewhat larger, amounting to $1.68 \pm .55$ per cent. This is on the borderline of probable statistical significance, and is in the same direction as the difference in absolute variability.

The degree of relative variability exhibited in TIAL (coefficient of variation of 10 to 12 per cent) is moderate in the scale of human char-

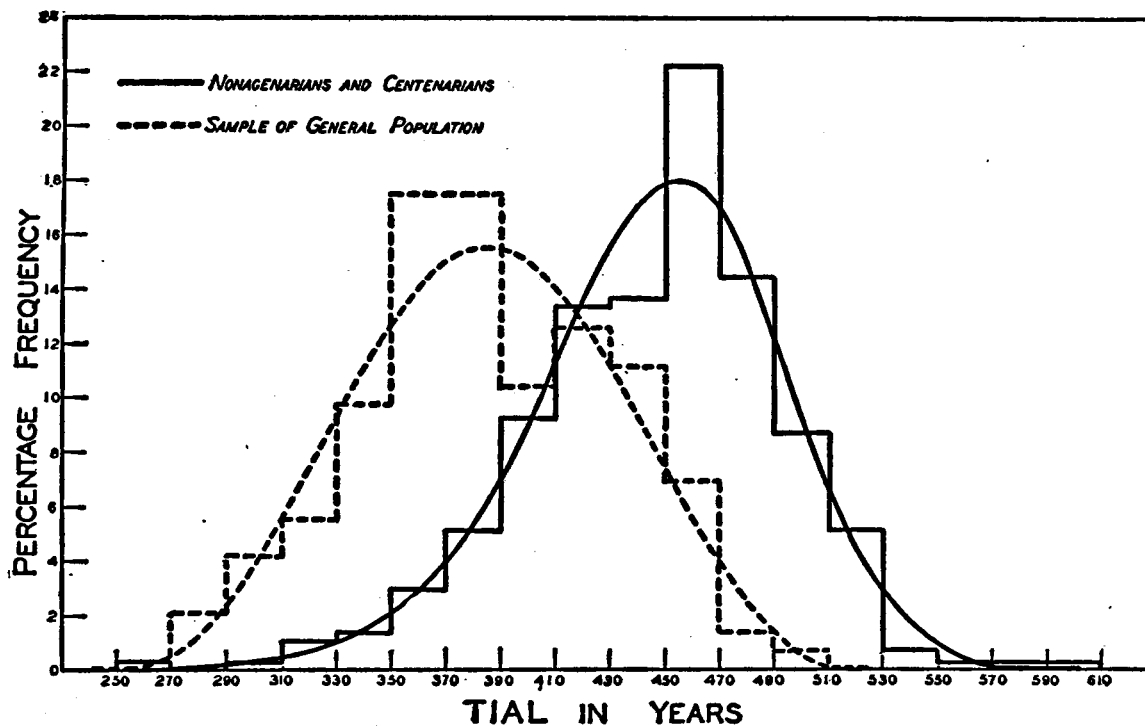


FIG. 11. HISTOGRAMS AND FITTED CURVES SHOWING THE DISTRIBUTION OF VARIATION IN TIAL FOR (A) NONAGENARIANS AND CENTENARIANS (LONG. SERIES), AND (B) COMPARISON GROUP (FHR SERIES)

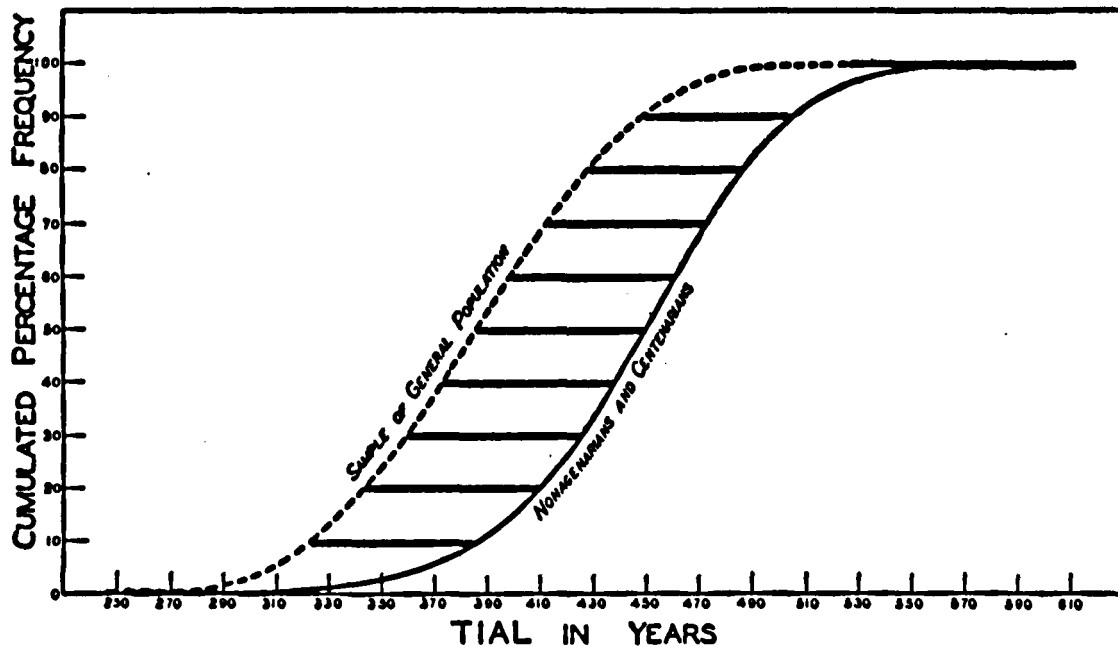


FIG. 12. CUMULATED (INTEGRAL) CURVE OF VARIATION IN TIAL IN THE LONG SERIES AND FHR SERIES. FOR FURTHER EXPLANATION SEE TEXT

VARIATION IN TIAL

acters generally.¹⁸ It compares in this respect roughly with such characters as body weight, skin pigmentation of whites, inter nipple breadth, height of mandible, relative cell volume of blood in active tuberculosis, lower nasal breadth in whites, etc.

Careful study of the data gives no indication that the variation in TIAL, in either series, is anything other than really continuous. In samples of the present size the irregularities in the frequency distribution cannot, in our opinion, be regarded as indicative of any real discontinuity in variation. By appropriate mathematical juggling we could graduate either of the TIAL distributions as the sum of two skew frequency curves just as could probably be done with practically any other frequency distribution whatsoever, but so far as any existing evidence goes the resultant would be only an expression of smart mathematical practice, and not in the least a description of a real natural phenomenon.

¹⁸ See Table 57 (pp. 347-349) of Pearl, R., *Introduction to Medical Biometry and Statistics*. Second Edit. *Philadelphia* (W. B. Saunders Co.), 1930.

CHAPTER VII

PATERNAL AND MATERNAL, MALE AND FEMALE, AND GENERATIONAL CONTRIBUTIONS TO TIAL



HAVING examined the variation in TIAL as a whole we may now proceed to its analysis. TIAL may be divided in various ways. Of these the following will be considered first:

$$TIAL = (a + b + e) + (c + d + f).$$

$(a + b + e)$ is the contribution to TIAL from the paternal side and $(c + d + f)$ the contribution from the maternal side.

Table II gives the biometric constants for these two moieties.

TABLE II
Biometric Constants for Paternal and Maternal Moieties of TIAL

CONSTANT	LONG. SERIES		FHR SERIES	
	Paternal $(a + b + e)$ (years)	Maternal $(c + d + f)$ (years)	Paternal $(a + b + e)$ (years)	Maternal $(c + d + f)$ (years)
Mean	223.48 ± 1.14	223.26 ± 1.06	196.71 ± 1.68	188.04 ± 1.84
Standard deviation ...	32.34 ± .81	30.11 ± .75	29.82 ± 1.19	32.54 ± 1.30
Coefficient of variation ...	13.85 ± .35	12.72 ± .32	15.16 ± .62	17.31 ± .71

It will be noticed at once that the sums of the mean paternal and maternal components of TIAL in Table II do not exactly equal the means and medians of the total TIALs in Table 10. The discrepancies arise because of the effects of grouping the frequency in 20-year classes in the computations. In making Table II the actual recorded ages of $(a + b + e)$ were separately summed for each individual propositus.

These sums were then put into a frequency distribution and the individuals in a class were assumed, as usual, to center at the mid-point of that class. The maternal component was dealt with in the same way. Discrepancies of the sort observed may be expected to arise under this procedure, even though the computations are accurate at all stages. In order to make clear exactly what these computational discrepancies amount to in Table 11, and subsequent tables, we insert here Table 12. This table shows (a) the mean values got from a combined frequency distribution of components of TIAL, (b) the sums of the separately computed means of the several components, and (c) the differences between the two and their probable errors. The differences are taken as + when the sum of the mean of the components (b) is the larger value.

It is clear from Table 12 that the discrepancies between the summed means and the means computed from combined frequencies are in no case statistically significant in either series.

Having now cleared up this technical point we may return to the consideration of the relative contributions to TIAL from the paternal and maternal sides of the pedigrees as set forth in Table 11.

Of the relationships shown by the data of Table 11 perhaps the most striking is that whereas in the Long. Series the contributions to TIAL from the paternal side of the pedigree and from the maternal side (whether measured by means or medians) are identical within less than 4 months in a total of over 200 years, the same is not true for the FHR Series. In the FHR Series the contribution to TIAL from the paternal side is distinctly larger than that from the maternal. The difference in the mean contribution is $196.71 - 188.04 = 8.67 \pm 2.49$ years. The odds against this difference being a chance fluctuation of sampling are nearly 54 to 1. It may therefore be concluded that in this sample the immediate ancestors on the maternal side are probably definitely inferior in longevity to those on the paternal side, in the case of the FHR Series, the group of ordinary longevity.

The differences between the Long. Series and the FHR Series in respect of the mean contribution to TIAL from the paternal and maternal sides are:

$$\text{Paternal; } 223.48 - 196.71 = 26.77 \pm 2.03 \text{ years}$$

$$\text{Maternal; } 223.26 - 188.04 = 35.22 \pm 2.12 \text{ years}$$

TABLE 12
Different Methods of Computing Mean Values of TIAL and Its Components

COMPONENTS OF TIAL	LONG. SERIES			FHR SERIES		
	Mean computed from frequency distribution of summed observations (a)	Sum of means of components (b)	Difference (c)	Mean computed from frequency distribution of summed observations (a)	Sum of means of components (b)	Difference (c)
$e + f =$ Parental component	144.63	145.75	+1.12±1.27	114.34	115.66	+1.32±2.11
$a + b + c + d =$ Grandparental component	301.34	306.05	+4.71±1.71	270.14	274.27	+4.13±2.79
$(a + b + c + d) + (e + f) =$ TIAL ...	446.14	445.97	-.17±2.31	385.45	384.48	-.97±3.73
$a + b + e =$ Paternal component	223.48	226.22	+2.74±1.51	196.71	199.19	+2.48±2.30
$c + d + f =$ Maternal component	223.26	225.58	+2.32±1.46	188.04	190.74	+2.70±2.50
$(a + b + e) + (c + d + f) =$ TIAL ...	446.14	446.74	+.60±2.28	385.45	384.75	-.70±3.64
$a + c + e =$ Male component	222.71	224.91	+2.20±1.47	195.17	197.24	+2.07±2.29
$b + d + f =$ Female component	223.97	226.89	+2.92±1.48	190.14	192.69	+2.55±2.38
$(a + c + e) + (b + d + f) =$ TIAL ...	446.14	446.68	+.54±2.26	385.45	385.31	-.14±3.55
$a + b + c + d + e + f =$ TIAL	446.14	451.80	+5.66±2.18	385.45	389.93	+4.48±3.52

These are obviously significant differences. The immediate ancestors on the paternal side of this group of nonagenarians and centenarians show about 14 per cent more accumulated longevity than do the corresponding ancestors of the FHR group. On the maternal side the superiority amounts to about 19 per cent.

There appears to be no definitely significant difference in variability of the contributions to TIAL from either the paternal or the maternal side. This is true of both the Long. and the FHR groups.

C. Contributions to TIAL from Male and Female Ancestors

How does the contribution to TIAL from the three male immediate ancestors compare with that from the three female? Here we have

$$TIAL = (a + c + e) + (b + d + f).$$

The data are given in Table 13.

The three immediate male ancestors in the Long. Series have a mean summed longevity of 27.54 ± 1.99 years, or 14.1 per cent greater than that shown by the corresponding male ancestors in the FHR Series. The mean excess in longevity of the three immediate female ancestors in the Long. Series over the corresponding ancestors in the FHR Series is 33.83 ± 1.99 years, or 17.8 per cent.

In the Long. Series the female immediate ancestors show only a small superiority, insignificant statistically, over the males in summed longevity. One would expect mothers and grandmothers to be definitely older at death, on the average, than fathers and grandfathers, because of the general superiority of females over males in life duration, which is one of the earliest and best established generalizations of biostatistics. The present results suggest, though it would be hazardous to conclude, that in the immediate ancestry of extremely longevous persons the usual rule as to the sex difference in longevity does not hold with its usual force. More data than are at present available would, however, be required to establish such an exception.

In the FHR Series it appears that the immediate female ancestors as a group are inferior in summed longevity to the immediate male ancestors. The difference in the means amounts to 5.03 ± 2.36 years, which cannot be regarded as statistically significant.

In neither series of data is there any significant difference in variability, either absolute or relative, in the summed longevity of male as compared with female immediate ancestors.

TABLE 13
Biometric Constants for Male and Female Moieties of TIAL

CONSTANTS	LONG. SERIES		FHR SERIES	
	Male ancestors ($a + c + e$) (years)	Female ancestors ($b + d + f$) (years)	Male ancestors ($a + c + e$) (years)	Female ancestors ($b + d + f$) (years)
Mean	222.71 ± 1.09	223.97 ± 1.08	195.17 ± 1.67	190.14 ± 1.67
Standard deviation	30.89 ± .77	30.71 ± .77	29.51 ± 1.18	29.68 ± 1.18
Coefficient of variation	13.02 ± .33%	13.71 ± .33%	15.12 ± .62%	15.61 ± .64%

CONTRIBUTIONS TO TIAL

D. *Generational Contributions to TIAL*

A third way in which TIAL may be broken up is

$$\text{TIAL} = (a + b + c + d) + (e + f),$$

which will give separately the total grandparental and parental contributions.

Table 14 presents the biometric constants for this division of the material.

The four grandparents in the Long. Series exhibit a mean summed longevity 31.20 ± 2.45 years, or 11.5 per cent, in excess of that of the four grandparents in the FHR Series. Here again, just as in each case so far examined, it is seen that however TIAL is broken up into its components the superiority of the group of nonagenarians and centenarians over the FHR group (individuals not directly selected for longevity) in respect of ancestral longevity is marked and significant. As has already been pointed out, this grandparental difference between the two series cannot be accounted for in any significant degree by the manner of selection of the two series.

The two parents in the Long. Series have a mean summed longevity of 30.29 ± 1.86 years, or 26.5 per cent greater than that of the parents in the FHR Series.

Here we encounter for the first time a relationship which will reappear in various forms as we proceed. While there are but two parents as against four grandparents contributing to TIAL the excess of the mean summed longevity in the Long. Series as compared with the FHR Series is *absolutely* almost identically the same for the parental contribution as it is for the grandparental, and therefore relatively about twice as large. In short, it appears that high parental longevity is more important to the individual than high grandparental longevity in his own quest for the achievement of great age.

If each one of the six immediate ancestors made exactly equal contributions to TIAL the mean total contribution of the grandparents in the Long. Series would be two-thirds of the total, or 297.43 years. Actually the mean grandparental contribution was 301.34 years, or 3.91 years in excess of expectation on an equal contribution basis. On the same assumption the expected mean parental contribution in the Long. Series would be 148.71 years. The actual was 144.63, or 4.08 years less. In both cases these differences are small, indeed so small that,

TABLE 14

Biometric Constants for Grandparental and Parental Contributions to TIAL

CONSTANTS	LONG. SERIES		FHR SERIES	
	Grandparents ($a + b + c + d$) (years)	Parents ($e + f$) (years)	Grandparents ($a + b + c + d$) (years)	Parents ($e + f$) (years)
Mean	301.34 ± 1.31	144.63 ± .92	270.14 ± 2.07	114.34 ± 1.62
Standard deviation	37.04 ± .92	26.02 ± .65	36.77 ± 1.47	28.69 ± 1.14
Coefficient of variation	12.29 ± .31%	17.99 ± .46%	14.70 ± .60%	25.09 ± 1.06%

having regard to the probable errors involved, the conclusion would seem to be that *in the Long. Series* the grandparents and the parents, as groups, contributed so nearly their respective two-thirds and one-third to TIAL as to make no matter practically.

The case is different in the FHR Series. There the expected grandparental contribution to TIAL, on the assumption of equal individual ancestral longevity, is 256.97 years. The actual is 270.14 years, an excess over expectation of 13.17 years. The expected parental contribution of one-third of TIAL is 128.48 years. The actual parental contribution is 114.34 years, an amount 14.14 years in defect of expectation. In other words, in the FHR Series the parents were relatively short lived. A part of this is probably a purely statistical consequence of the manner in which the group was formed. Some judgment as to how much may be formed after the data of Chapter IX have been presented.

CHAPTER VIII

INDIVIDUAL CONTRIBUTIONS TO TIAL



THE discussion in the preceding chapter has brought us to the point where it is necessary and desirable to examine the contribution of each individual ancestor to the total immediate ancestral longevity of the propositus.

Table 15 gives the biometric constants for the six individual ancestors whose combined contributions make up TIAL, that is where

$$\text{TIAL} = a + b + c + d + e + f.$$

The first thing that strikes one in examining Table 15 is the great regularity of the constants for the ages at death of the six immediate ancestors in both series. The mean ages of the four grandparents, in each series, agree with each other to a degree well within the fluctuations of random sampling. The same is true of their standard deviations and coefficients of variation. The same thing is also true of the parents in the Long. Series, but not in the FHR Series.

The individual ancestors in the Long. Series have higher mean ages at death, and lower coefficients of variation, in each case, than do the corresponding ancestors in the FHR Series. The standard deviations in the two series are plainly not significantly different from each other. The absolute and relative differences in the mean, together with the probable errors, and the absolute differences and probable errors of the coefficients of variation are shown in Table 16.

Each of the four grandparents in the Long. Series had an average duration of life from 10 to 14 per cent (11.6 average) longer than the corresponding ancestor in the FHR Series. These differences are certainly significant, being about 7 times their probable errors. The differences in grandparental coefficients of variation, the FHR Series being the more variable in each case, can only be regarded as probably significant statistically. Except in one case (mother's mother) they are just under three times the probable error.

The excess longevity of each of the parents in the Long. Series as compared with the FHR Series is much larger than the grandparental excess, in fact nearly double.

TABLE 15
*Biometric Constants for Age at Death of the Six Immediate Ancestors of the Propositus
 in the Long. Series and the FHR Series*

ANCESTRY	MEAN		STANDARD DEVIATION		COEFFICIENT OF VARIATION	
	Long. Series (years)	FHR Series (years)	Long. Series (years)	FHR Series (years)	Long. Series (per cent)	FHR Series (per cent)
a. Father's father ...	76.75± .56	68.99± .92	15.73± .39	16.35± .65	20.49± .53	23.70± 1.00
b. Father's mother ..	77.05± .56	70.10± .93	15.87± .40	16.55± .66	20.60± .54	23.61± .99
c. Mother's father ..	75.74± .55	68.15± .93	15.64± .39	16.40± .65	20.65± .54	24.07± 1.01
d. Mother's mother ..	76.51± .54	67.03± .96	15.43± .39	17.08± .68	20.16± .52	25.48± 1.07
e. Father	72.42± .60	60.10± .87	16.86± .42	15.37± .61	23.28± .61	25.57± 1.08
f. Mother	73.33± .64	55.56± 1.04	18.03± .45	18.39± .73	24.59± .65	33.10± 1.46

TABLE 16

ANCESTRY	EXCESS OF LONG.	PERCENT- AGE EXCESS	DIFFERENCE IN
	MEAN OVER FHR MEAN (years)		RELATIVE VARI- ABILITY (LONG. C. OF V) — (FHR C. OF V.)
a. Father's father	7.76 ± 1.08	11.2	-3.21 ± 1.13
b. Father's mother	6.95 ± 1.09	9.9	-3.01 ± 1.13
c. Mother's father	7.59 ± 1.07	11.1	-3.42 ± 1.15
d. Mother's mother	9.48 ± 1.10	14.1	-5.32 ± 1.15
e. Father	12.32 ± 1.06	20.5	-2.29 ± 1.24
f. Mother	17.77 ± 1.22	32.0	-8.51 ± 1.60

The meaning of the data set forth in Tables 15 and 16 will perhaps be made clearer by an examination of Figures 13 to 15, which put the results graphically in the form of pedigrees. All three of these diagrams are drawn on the same plan. Figure 13 deals with mean ages. In the left-hand panel the pedigree gives, by the figures within the sex signs, the mean age at death of each ancestor in the Long. Series, and within the rectangular box at the bottom (a) the mean living ages of the *propositi*, and (b) the expected mean total longevities when they are all dead. The pedigree in the right hand panel does the same thing for the FHR Series. In the middle panel the pedigree shows in the same way the differences, both absolute (upper figures, years) and relative (lower figures, percentages) between the Long. and the FHR Series. The percentages are taken as of the difference to the smaller component entering into it.^{10a}

Comparing pedigree A of Figure 13 with pedigree B leads to the following broad general result: We select two groups of living persons (the *propositi*) such that the mean living age of one group (A) is 95.5 per cent greater than that of the other group. On its face this is a stringent selection for diversity. But the *parents* of these two diverse groups differ in completed longevity not by 95 per cent, but by an

^{10a} By an inadvertent error in drafting, first discovered in the proof, the percentage 37.6 at the bottom of the middle panel of Fig. 14 is incorrect. It should be 36.0.

INFLUENCE OF IMMEDIATE ANCESTRY UPON LONGEVITY MEANS

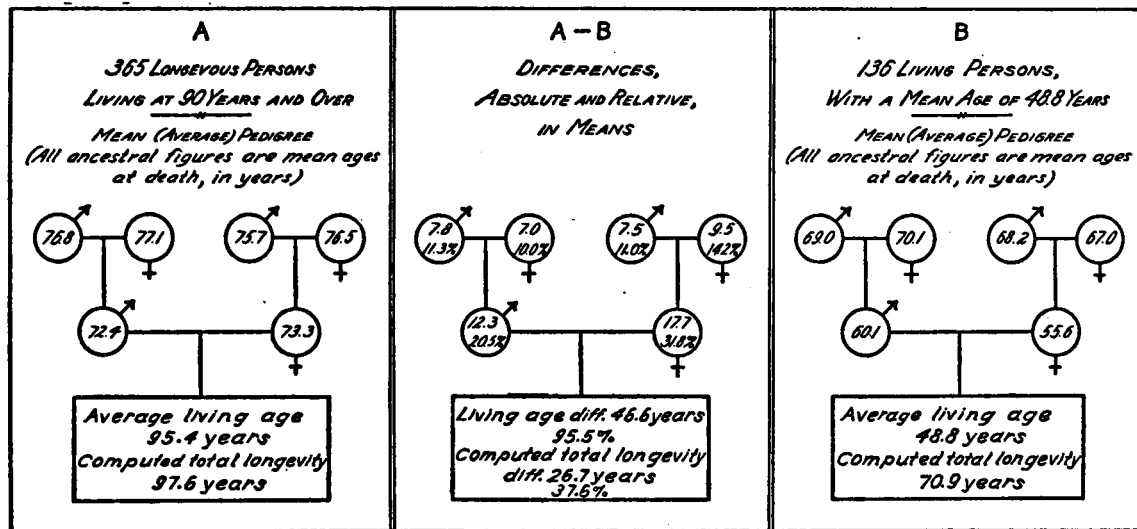


FIG. 13. INFLUENCE OF IMMEDIATE ANCESTORS UPON MEAN (AVERAGE) LONGEVITY
FOR FURTHER EXPLANATION SEE TEXT

INFLUENCE OF IMMEDIATE ANCESTRY UPON LONGEVITY MEDIANS

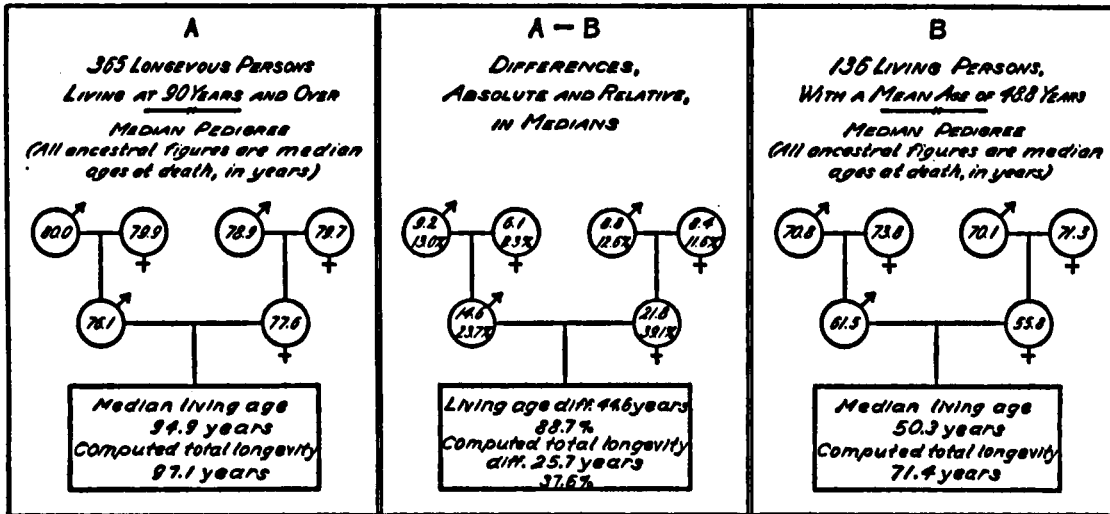


FIG. 14. INFLUENCE OF IMMEDIATE ANCESTRY UPON MEDIAN LONGEVITY

INFLUENCE OF IMMEDIATE ANCESTRY UPON LONGEVITY
STANDARD DEVIATIONS

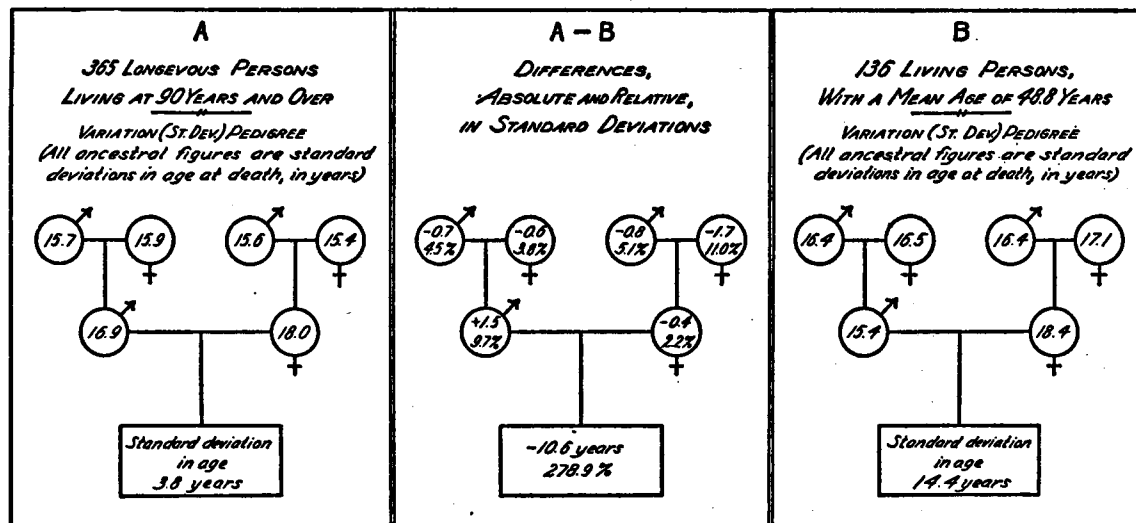


FIG. 15. VARIATION IN ANCESTRAL LONGEVITY

average of only about 26 per cent. And their *grandparents* differ in completed longevity by an average of only 11.6 per cent. To put it another way the parents of two groups widely divergent in mean realized longevity up to the time of record differ rather less than a third as much in their completed longevity. It must, however, be clearly recognized that a considerable part of the great divergence between the *propositi* of the two series in mean living age arises from the fact that it is *living* age under discussion. If we put in place of mean living age the expected mean *final* longevities (realized plus expected from the life table) as computed earlier we find the computed total longevities of the *propositi* (and the resultant differences) given at the bottom of the panels of Figures 13 and 14. They show that even upon the basis of completed longevity the *propositi* of the two series are more different from each other than are their respective parents.

The two groups of grandparents are less divergent from each other in longevity than are the parents—are in fact plainly quite close to the average longevity of grandparents in general. If it were possible to get the data for a great-grandparental generation we should probably find, in samples of the order of size of these here dealt with, that each of the two sets of great-grandparents were practically random samples of great-grandparents in general, and indistinguishable from each other.

This result is, of course, merely one particular example of a general rule, which has been strikingly stated by Pearson¹⁰ in the following passage:

Twenty generations ago each one of us, but for cousin or other blood marriages, would have over a million ancestors of the same generation, and that is only 600 to 700 years ago. You will see that the ancestors of any one of you must 1000 years ago have been nearly synonymous with the total population of Great Britain and therefore their average was mediocre or your mid-ancestor of that generation was identical with the type of the inhabitants of this country or rather of a still wider range of mankind. I have endeavored to follow back the ancestry of Charles Darwin and in those lines in which I can follow it, I find that a thousand years ago his known ancestors were scattered over the whole face of Europe, and stretched over Russia to Persia and through Constantinople to Asia Minor. No escape from this burden of ancestry is possible either in man or beast except by isolation and inbreeding.

¹⁰ Pearson, K. On a new theory of progressive evolution. *Ann. of Eug.*, Vol. 4 pp. 1-40, 1930.

Let us examine a little more closely the 10th generation of ancestry; we each had 1024 ancestors, between 300 and 400 years ago. Their average must be very nearly mediocrity, or type, for 1000 is a fair sized sample anthropometrically, as you would appreciate if you attempted to measure 30 or 40 characters in 1000 skulls! Indeed I may bring it still further home, for it would be difficult to find a man with 16 exceptional great-great-grandparents, and the average even of 16 individuals, if they are selected at random, will not be very different from mediocrity for any single character.

Figure 14, constructed on the same plan as Figure 13, but for median ages, gives the same general result as we have seen from the means.

Figure 15, in which the pedigrees are for absolute variability as given by the standard deviation, shows that the great difference in this respect between the *propositi* in the Long. and the FHR Series in respect of living age diminishes to very small and statistically insignificant amounts in the parental and grandparental generations. Such ancestral differences in variability as there are, however, are all of the same sign except in the case of the fathers. The ancestry of the individuals in the FHR Series is, with the exception noted, consistently slightly more variable in life duration than that of the individuals in the Long. Series.

CHAPTER IX

LIVING AGE AND TIAL

IT IS evident *a priori*, and has already been mentioned earlier, that if families are chosen, as are those in the FHR Series in this book, entirely at random relative to age, but with the requirements (a) that all the ancestors shall be dead, and (b) that in the resultant offspring sibships there shall be at least one living person, there will be a tendency for the mean value of TIAL for any group of such families to increase as the mean age of any single living person (as say the oldest) or the mean age of all living persons in the offspring sibships in the groups increases. Let the particular living person chosen in each case from the offspring sibship be called the propositus, as in this study. Then this positive correlation between living age of propositus and his TIAL will be the resultant of the combined action of two sorts of causes; one, the inheritance of duration of life, the other the purely arithmetical consequences of the rules of selection stated above. The relative importance of these two sets of causes in any particular case will vary according to the age group of propositi dealt with. Thus in a group like our Long. Series of non-agenarians and centenarians the purely arithmetical factor will presumably be either absent or relatively unimportant in bringing about whatever correlation may be observed between TIAL and age of living propositus, because in both ancestral and offspring generations everyone will have had plenty of time to do any dying to which he is biologically predisposed. Whatever correlation is observed in such a group will therefore be preponderantly due to the inheritance of longevity factor. On the other hand if a group of living propositi aged say 20-29 is taken, the situation will clearly be somewhat different. The arithmetic factor will presumably be of greater importance, because for a living person aged 25 to have all his ancestors dead it is necessary that some at least of the six immediate ancestors shall have died at fairly young ages.

The discussion will have made it clear why it is desirable to examine carefully into, first, the question as to how TIAL does in fact change in both the Long. and the FHR series dealt with in this book as the ages

TABLE 16a

Biometric Constants for the TIALs of Groups of Propositi of Increasing Living Ages

ITEM NO.	GROUPS OF PROPOSITI BY LIVING AGE	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
<i>FHR Series</i>					
1	Propositi living at 10 years and over.....	385.5± 2.7	382.4± 3.4	47.0± 1.9	12.20± .49
2	Propositi living at 20 years and over.....	386.9± 2.7	384.3± 3.4	46.6± 1.9	12.05± .50
3	Propositi living at 30 years and over.....	391.7± 2.7	388.6± 3.4	44.3± 1.9	11.31± .49
4	Propositi living at 40 years and over.....	395.8± 2.9	395.3± 3.6	44.0± 2.1	11.12± .53
5	Propositi living at 50 years and over.....	401.1± 3.8	405.6± 4.7	46.6± 2.7	11.61± .67
6	Propositi living at 60 years and over.....	422.7± 5.0	426.7± 6.3	40.2± 3.5	9.52± .85
7	Propositi living at 70 years and over.....	448.6± 10.5	460.0± 13.1	38.3± 7.5	8.55± 1.68
<i>Long. Series</i>					
8	Propositi living at 90 years and over.....	446.1± 1.7	452.1± 2.1	46.9± 1.2	10.52± .26
9	Propositi living at 95 years and over.....	445.5± 2.3	449.2± 2.9	48.1± 1.7	10.79± .38
10	Propositi living at 100 years and over.....	449.2± 3.1	452.5± 3.9	35.4± 2.2	7.88± .50
11	Propositi living at 105 years and over.....	442.9± 9.9	435.0± 12.4	36.1± 7.0	8.16± 1.60

of the living *propositi* change; and, second, the theoretical consequences and limitations of what we have called above the arithmetical or statistical factor. The data presented in this book suggest that the longevous individuals of the Long. Series constitute a group of human beings innately and genetically differentiated biologically from the general run of mankind in respect of their enduring viability. But is this really the case, or are we deluding ourselves by the observation of a merely arithmetical or statistical phenomenon without any particular biological significance?

Table 16a and Fig. B throw some light on this question, and in doing so bring out a point of possible significance for the further genetic analysis of longevity. Table 16a gives the standard biometric constants for TIAL for groups of living *propositi* successively 10 years of age and over, 20 years of age and over, 30 years of age and over, and so on.

The means of Table 16a are shown graphically in Fig. B. These means are fitted with three straight lines, by the method of least squares. The first of these lines is fitted to the data of Items 1 to 5 inclusive (*propositi* 10 years and over to and including *propositi* 50 years and over). Its equation is

$$Y = 380.44 + 0.389 X, \quad (i)$$

where Y is TIAL and X is mean age of living *propositi*. In Fig. B this line is shown as a solid line through the range of observations to which it is fitted. It is extrapolated to ages beyond 50 as a dash line.

The second straight line is fitted to the means recorded as Items 5, 6 and 7 (*propositi* 50 years and over through *propositi* 70 years and over). Its equation is:

$$Y = 286.90 + 2.28 X \quad (ii).$$

This line is plotted as a solid line through the observations to which it is fitted.

Finally the third straight line is fitted to the means recorded as Items 8 to 11 inclusive (*propositi* 90 years and over through *propositi* 105 and over). Its equation is:

$$Y = 436.80 + 0.101 X \quad (iii)$$

This line is plotted as a solid line through the observations to which it is fitted, and is extrapolated backwards from 90 as a dash line.

Let us now try to find out what the observations set forth in Table 16a and Fig. B really mean. We are dealing on the one hand with the

relationship between the ages at the time of observation of two groups of living persons, each of gradually narrowing and ascending ranges of living age; and the TIAL figures produced by their immediate ancestors, all of whom are dead, on the other hand. Living age at the time of observations means, and can tell us no more than, that the individual had been able to survive *at least* that long in the struggle for existence—the battle against disease and other environmental buffetings. It tells us nothing about how long that individual, as individual, will survive after the time of observation.

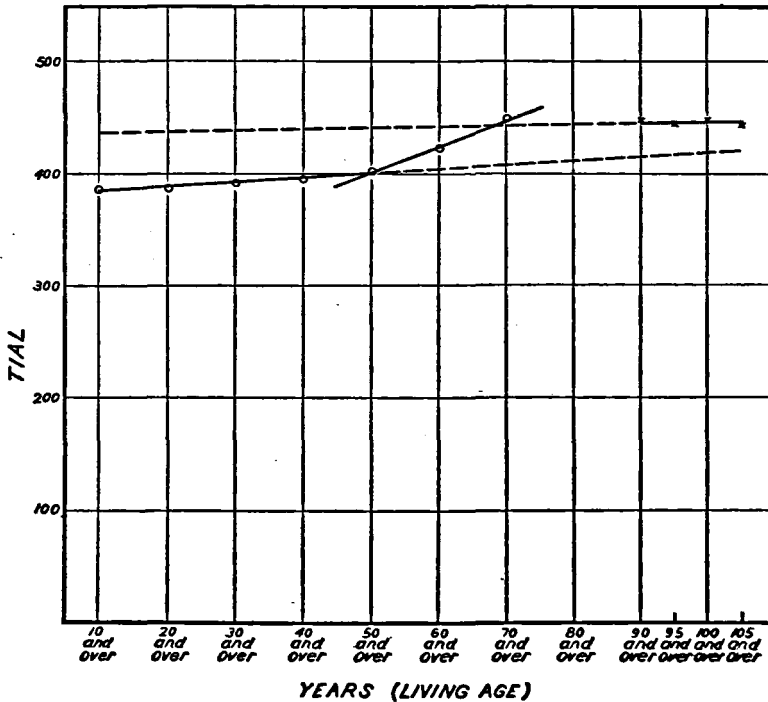


FIG. B. SHOWING THE TRENDS OF TIAL IN RELATION TO MEAN AGE OF LIVING PROPOSITI. The observations from the FHR Series are given as circles, and those from the Long. Series as crosses. For further explanation see text.

Let us confine our attention first to the figures for the FHR Series exclusively. We see that if we consider the whole group (ages 10 years and over) it covers in living ages nearly the whole normal life span in

the range of living ages, and has a mean TIAL of 385.5 years. Now if we drop out of the group those who had not attained the age of 20 years at the time of observation, and confine our attention to the remainder, namely those who at the time of observation had survived 20 or more years, the mean TIAL of this group is higher than that of the former group, but only a little higher, actually 1.4 ± 3.8 years, or about 0.2 year per immediate ancestor on the average.

Similarly if we drop out those who had not reached 30 years of age at the time of observation, and consider only those who had survived 30 or more years after birth, again the mean TIAL is higher than before but again only by the relatively small amount of 4.8 ± 3.8 years, or 0.8 year for each of the six immediate ancestors, on the average. Dropping out those who had not reached 40 years of age at the time of observation raises the mean TIAL again, but only by 4.1 ± 4.0 years, or just under 0.7 year, on the average, for each immediate ancestor. If all the propositi who had not reached the age of 50 years are dropped, the remaining survivors at ages of 50 years and over have a mean TIAL 5.3 ± 4.8 years higher than the last, or just under 0.9 year per immediate ancestor on the average.

The position up to this point then is that as we take groups of living propositi surviving at ages of 10 and over, 20 and over, 30 and over, 40 and over, and 50 and over, there is a steady but slow increase in mean TIAL, the difference between any two successive groups being statistically insignificant in comparison with their probable errors, and absolutely so small as to amount always to less than a year's increase in average longevity of any one parent or grandparent when distributed among all six of these ancestors. But these differences are all in the same direction and therefore cumulative, so that if all those surviving to 10 years of age and over be compared with all those surviving to 50 years of age and over the difference amounts to 15.6 ± 4.7 years. This is probably statistically significant, and amounts to 2.6 years for each of the six immediate ancestors on the average. The fitted line of equation (i) in Fig. B fits the observations very closely, or, to put it the other way about, the observed mean TIALs of the groups of propositi we have been discussing fall with remarkable exactness near a straight line of slight upward slope.

But when we go on beyond the group of living propositi 50 years of age and over, the situation changes abruptly and markedly. The

mean TIAL for the group surviving to 60 years of age and over is 21.6 years higher than that for the group surviving to 50 years and over. And the mean TIAL for the group surviving to 70 years and over is 25.9 years higher than that for the 60 years and over group. The numbers involved are to be sure small, and the probable errors consequently large, but that the upward slope of the line of mean TIALs has become abruptly much steeper admits of no reasonable doubt.

If we turn now to the data for the Long. Series we see that again the groups of *propositi* of successively higher living age composition and progressively narrower age range exhibit mean TIALs lying very nearly on a straight line with very small upward slope, but this line lies generally at a definitely higher level than that for the 10 to 50 year group first examined.

These observations set forth in Tables 16a and Fig. B suggest that there may exist three groups of persons differentiated in respect of innate, genetic longevity. One of these, the short-lived group, would include those persons who are so biologically constituted that they die at ages under 50 years or thereabouts, and have relatively low average TIALs, probably generally not higher than about 350 years. From the present data it is impossible to determine this latter point exactly, because we are here dealing with living *propositi* throughout. To settle the matter it will be necessary to make a special *ad hoc* investigation of the mean TIALs of persons dying at ages under 50 years. This we hope to be able to do later. The second, intermediate or transitional group would appear to be made up of persons who are so biologically constituted that they die at ages roughly between 50 and 70 years. They probably have average TIALs ranging roughly between 350 and 400 years. Presumably it is to this group, if it is a reality, that the majority of human beings belong who succeed in living to adulthood. They are the folk of average life duration. Finally the third or long-lived group would be made up of those who are so constituted biologically as to live beyond 70 years of age. They will probably have average TIALs well above 400 years.

It is to be understood clearly that this classification is, on the basis of present knowledge, much more hypothesis than established fact. But the smoothness of the trends of the data given above, together with all the other supporting evidence from the data in this book, would certainly seem to warrant regarding it as a promising hypothesis for further

testing and particularly along genetic directions. *The lines of equations (i) and (iii) do not intersect at any point within the human life span.* The slopes of both of these lines (those for the short-lived and the long-lived respectively) are very small, and in marked contrast to that of the intermediate group.

On the other hand it must be remembered that the total material here dealt with is not large, and consequently the probable errors are of a magnitude which makes it impossible to regard Table 16a as in any sense probative of the hypothesis it suggests. The limiting ages suggested for the three classes may require alteration and refinement when additional evidence is at hand.

Furthermore it must be recognized that the evidence for the two extreme genetic groups or classes (short-lived and long-lived respectively) is more cogent and convincing than that for the intermediate class. In fact it may be that what we have called the intermediate class does not exist as a specific genetic group at all, but represents the transitional or overlapping age zone between the other two classes. We do not regard the evidence available from the present study as adequate to settle this point now. Nor have we any desire or intention to press the suggested genetic hypothesis to its limits at present, or indeed until such time as we have at hand critically adequate evidential material for its testing. We are of the opinion—shared we believe by not a few temperate minded biologists—that the case of modern genetics and particularly human genetics is being seriously harmed by wildly uncritical extensions of the gene theory, for which the observed evidence is either wholly lacking or is absurdly inadequate.

Let us now turn to an examination of the theoretical aspects of what we have called the arithmetical or statistical factor in the positive correlation between mean TIAL and age of living progeny. It is evident *a priori* that two factors, the age limitations on human reproduction on the one hand, and the upper limit of the human life span on the other hand, must set definite limits to the action of this arithmetic factor. What are these limits?

Let us consider first the case of a person A living at the age of 10 years. The theoretical *lowest* possible limit to the TIAL of such a person may be taken for purposes of approximation as 90 years. This is arrived at on the following postulates: (a) that A's father and mother were each exactly 15 years old when A was born; and (b) both died an

infinitesimal fraction of a second after that blessed event; and (c) that each of the four grandparents performed in exactly the same way. This assumes that human beings do not reproduce at ages below 15 years. We are aware that this is not strictly or universally true. But for purposes of the approximate computations upon which we are entering the error made on this assumption is negligible. Any year's natality statistics show that the numbers of births from mothers and fathers both under 15 years of age are negligibly small.

For this same individual A the *maximum* TIAL theoretically possible may be taken as 520 years, this figure being reached on the basis of the following postulates: (a) that A's father and mother were exactly 50 years of age when A was born; (b) that both died an infinitesimal fraction of a second before the moment when A became 10 years of age, and they became 60 years of age; and (c) that each of A's grandparents died at the age of 100 years. These postulates assume that, save for statistically negligible exceptions, human reproduction is finished at age 50 (see footnote 51 *infra* on this point), and that 100 years represents approximately the upper limit of the human life span. The errors involved in both these assumptions are so small that they may be neglected in an approximate computation.

The mid-point between the theoretical minimum and maximum TIAL for individual A is then 305 years. Let us regard this for the sake of the argument as though it were the mean TIAL for a group of A's, and let us further assume that generally TIAL frequency distributions generally approximate to the same *form* regardless of the age of the propositus. As a matter of fact our data indicate that this assumption comes sufficiently close to the actual fact.

Now consider the case of an individual B who is living at the age of 70 years. The theoretical *minimum* limit of his TIAL will again be 90 years, on precisely the same reasoning as fixed A's at that figure. B's theoretical *maximum* limit of TIAL will be 600 years, on the reasoning: (a) that B's father and mother were exactly 50 years of age when B was born; (b) that each of them lived to the upper limit of the human life span (100 years), which made them necessarily die when B was 50 years old instead of when he was 70, because to have lived till B was 70 years of age would have required them to live to be respectively 120 years old, which is beyond the agreed upon limit of the life span; and (c) that as before each of B's grandparents died at the age of 100 years.

Following the above reasoning Table 16b has been prepared.

TABLE 16b

*Theoretical Minimum, Maximum, and Mid-TIALs for Propositi
of Different Living Ages*

LIVING AGE OF PROPOSITUS (years)	THEORETICAL MINIMUM TIAL (years)	AVERAGE AGE AT DEATH OF 6 IMME- DIATE ANCESTORS PRODUCING MINI- MUM TIAL (years)	THEORETICAL MID-TIAL (years)	THEORETICAL MAXIMUM TIAL (years)	AVERAGE AGE AT DEATH OF 6 IMME- DIATE ANCESTORS PRODUCING MAXI- MUM TIAL (years)
10	90	15	305	520	86.7
20	90	15	315	540	90.0
30	90	15	325	560	93.3
40	90	15	335	580	96.7
50	90	15	345	600	100.0
60	90	15	345	600	100.0
70	90	15	345	600	100.0
80	90	15	345	600	100.0
90	90	15	345	600	100.0
100	90	15	345	600	100.0

Table 16b brings out a point of great importance, namely that in the limiting case, what we have called above the arithmetic factor in raising TIAL with advancing living age of propositus *can operate only up to about 50 years of living age of propositus*, owing to the limitations of the age range of human reproductivity and of the human life span. The mid-TIALs rise from propositus age 10 to propositus age 50, and then continue at a constant value to the end of the life span. As we go beyond age 50 some other factor must be called upon theoretically to account for increasing values of TIAL, if and when observed. Presumably this factor is, in the main, the factor of inheritance of longevity.

Another noteworthy feature of Table 16 is the gradual character of the rise of the mid-TIAL values from the 10 year old propositus to the 50 year old propositus. We shall come back again to this point later.

At this point it may be objected that in the reasoning leading up to Table 16b we have set the theoretical minimum TIAL at too low a figure, lower than would practically ever occur in actual life. This is so. But the intention of Table 16b as stated above was to set absolutely extreme, outside limits to TIAL to a first degree approximation at least. And that is what Table 16b does.

But suppose we now see what happens when we take a lower limiting value for TIAL more nearly in accord with observations as to what does actually occur in human society under present conditions. In our collection of data the lowest observed TIAL was 254 years. To be conservative and make a reasonable allowance for sampling errors suppose we take the lower limiting value for TIAL in a practical world of real human beings as 240 years, and set up a table exactly like 16b, save for the substitution of the 240 year minimum in place of the 90 year minimum. This is done in Table 16c.

TABLE 16c

Hypothetical Minimum, Maximum, and Mid-TIALs for Propositi of Different Living Ages Upon the Assumption that the Lower Limit of TIAL is 240 Years

LIVING AGE OF PROPOSITUS (years)	MINIMUM TIAL (years)	MID-TIAL (years)	MAXIMUM TIAL (years)
10	240	380	520
20	240	390	540
30	240	400	560
40	240	410	580
50	240	420	600
60	240	420	600
70	240	420	600
80	240	420	600
90	240	420	600
100	240	420	600

It is evident that nothing new in principle comes out of Table 16c when compared with 16b. The effect of the so-called arithmetic factor

stops after 50 years of age of propositus just as before. The only difference produced by taking a higher minimum TIAL is to raise the mid-TIAL values by 75 years throughout.

There is one final stage of this discussion to be now considered. In Table 16a we did not, as in 16b and 16c, deal with propositi of single fixed living ages, but took in each group of propositi individuals aged *x* and over. This had obviously the effect of weighting all values with the accumulated propositi of higher living ages in the sample. We shall now present in Table 16d the results of doing the same thing with the mid-TIALs of Tables 16b and 16c. In computing the mean mid-TIALs of Table 16d weighting factors proportional to the actual numbers in each group in our FHR Series have been used.

TABLE 16d

Hypothetical Mean Mid-TIALs Based (a) Upon the Assumption Underlying Tables 15b and 15c, and (b) Upon the Same Group Frequencies as are Involved in the Actual Observations of Table 16a

LIVING AGES OF PROPOSITI (years)	MEAN MID-TIALS ASSUMING 90 YEARS TO BE A MINIMUM POSSIBLE TIAL VALUE (years)	MEAN MID-TIALS ASSUMING 240 YEARS AS THE LOWER LIMIT OF TIAL UNDER ACTUAL CONDITIONS (years)
10 and over..	323.3	398.3
20 and over..	328.8	403.8
30 and over..	334.5	409.5
40 and over..	340.1	415.1
50 and over..	345.0	420.0
60 and over..	345.0	420.0
70 and over..	345.0	420.0

Again it is seen that the effect of the arithmetic factor in raising the mean TIAL value disappears after the age 50 and over group is passed. A comparison of the mean mid-TIAL values of Table 16d with the actually observed mean TIALs in the first column of Table 16a shows that the slopes of the lines of Table 16d from, and including,

the age 10 and over group to the age 50 and over group are very nearly the same as the slope of the corresponding actual means in Table 16a. But it also clearly appears that the 90 year minimum TIAL value of Table 16b is considerably too small, and the 240 minimum TIAL of Table 16c is somewhat too large to agree with the actual facts in this material.

By a simple adjustment of differences it appears that a minimum value for TIAL very close to that indicated by our actual FHR Series is 205.7 years. Table 16e shows the effect of substituting this value into the same calculations as those leading to Table 16d.

TABLE 16e

Hypothetical Mean Mid-TIALs, Based Upon the Assumptions Underlying Table 16d, But With an Assumed Minimum TIAL of 205.7 Years

LIVING AGE OF PROPOSITI (years)	MEAN MID-TIALS ASSUMING 205.7 YEARS TO BE THE MINIMUM TIAL (years)	DIFFERENCES FROM OBSERVED MEAN TIALS OF TABLE 16a (years)
10 and over..	381.1	+4.4
20 and over..	386.6	+0.3
30 and over..	392.4	-0.7
40 and over..	397.9	-2.1
50 and over..	402.9	-1.8

It seems to us that the results of Table 16e are somewhat remarkable. They are reached by only the assumptions (a) that the minimum TIAL that occurs in practice is 205.7 years, and is the same for all groups of propositi; (b) that the maximum possible TIALs are those given in Table 16b, computed by methods there explained; (c) that the mid-point between the minimum and maximum TIAL for any group is a sufficient approximation to the true mean TIAL of the group; and (d) that the relative frequencies (weights) attached to each group are the same as those actually observed in the FHR Series.

With these assumptions we are able to predict the actually observed mean TIAL values for groups of living propositi between (and including) ages 10 and over to 50 and over, with an average error, regardless of signs, of 1.86 years, or about 0.5 per cent, or 5 years in a thousand of the variable.

So far as we are aware this chapter comprises the first systematic attempt to evaluate precisely for a particular set of selective conditions the significance of what we have called the arithmetic factor affecting the interpretation of results got from human family data regarding the inheritance of longevity. All students of the subject have been aware of the existence of this factor as a complication in dealing with family data, but the magnitude of its effects, or the limitations to its operation, have not been clearly understood, or precisely worked out. The present analysis, as has already been implied, applies in its totality only to the particular set of selective conditions upon the basis of which the samples of individuals for study were drawn in the present investigation. But it seems likely that the results obtained in this chapter will be useful for future workers in analyzing the similar problems which will appear in their work when samples of material are drawn from family data under defined and uniform conditions for the study of human genetic problems.

The results of this chapter may be summarized in general terms as follows:

1. As the living age of progeny increases, the ages at death of their six immediate ancestors tend also to increase, whether taken in the aggregate or singly.
2. The rate of increase in ages at death of the ancestry is very slow up to progeny living ages of 50 years, and still slower for progeny living ages of 90 years and beyond. Between progeny living ages of 50 and 70 the increase in ancestral ages at death is at a much more rapid rate.
3. The increase in ancestral ages at death for groups of progeny individuals of living ages below 50 appears to be solely due to an arithmetic factor, under the conditions of selection of material rigidly adhered to in this investigation; and to be due to the operation of the inheritance of longevity factor for groups of progeny individuals of living ages over 50 years.

4. In the light of the above results it appears that no important result or conclusion of the present investigation, in either the preceding or following chapters, is vitiated by the existence of the arithmetic age factor operating in family data selected according to the rules rigorously followed in this study.

5. The results of this chapter suggest that there may exist two or possibly three classes of human beings differentiated in respect of innate, genetic longevity, or viability, viz. those dying under 50 years of age; those dying at ages between 50 and 70 years of age; and finally those dying at ages above 70 years. The evidence for the first and third of these classes is stronger than that for the second.

CHAPTER X

BIOMETRICAL COMPARISONS



LET us now consider some comparative results. The question of the mean age at death, for example, of particular ancestors (say fathers or grandfathers) is an extremely interesting one, and one about which comparatively little is known. Similarly one would like to know something of the variability in longevity of ancestors. It will therefore be useful to bring together in a comprehensive table the available data upon these points. This is done in Table 17, which contains means, standard deviations, and coefficients of variation for age at death of parents and grandparents. Data regarding more remote ancestors have apparently not been published.

In computing the average figures at the end of each section of Table 17, to serve as a first approximation to norms until more and better data can be added to what is here tabulated, the following procedure was followed. For the unweighted averages (1) the *means* for cases where N , mean and S. D. were given were added and divided by the number of such cases; (2) the *standard deviations* for the same cases were added and divided by the number of such cases; (3) the mean standard deviation as described under (2) was multiplied by 100 and divided by the average mean computed as described under (1) to get the average *coefficient of variation*; (4) to get the probable errors of the averaged constants the average S. D. (2) and the average C. of V. (3) were used, with the average N of the cases used. The procedure in the case of the weighted average constants was the same except that each constant was weighted in averaging with its N as tabled, but in computing the probable errors the same average N as in (4) was used. This is a conservative procedure. As a matter of fact there is but little difference between the weighted and unweighted average constants in any case. For grandparents no average constants are given because the material is too meager to make such a procedure of any value.

From an examination of Table 17, which summarizes essentially all the knowledge of the longevity of ancestors in man that has been

gained by the application of biometric methods to pedigree data, the following points worthy of note emerge:

1. The mean age at death of fathers ranges from 54.33 years for fathers of living tuberculous persons to 72.42 years for fathers of non-agenarians and centenarians, a range of 18.09 years. This is more than twice as great a range as is found for grandfathers, where the extremes are 68.15 years for maternal grandfathers in the FHR Series and 76.75 years for paternal grandfathers of nonagenarians and centenarians (Long. Series), a range of 8.60 years. But the available data for grandfathers are very meager. Presumably as further material from other differentiated samples becomes available the range of mean ages at death of grandfathers will widen somewhat. But it also must be remembered that there is some reason to believe that grandfathers in general will always prove to be a more homogeneous class of human beings in respect of age at death than parents; primarily because, as has already been suggested, they tend to be more nearly a random sample of the whole population in respect of genetic constitution. Even with the meager data available the coefficients of variation of Table 17 suggest that fathers tend slightly to be more variable individually in age at death than grandfathers, but the material available for comparison is so small that this can be no more than a tentative suggestion.

2. Mothers appear to be more variable individually in age at death than fathers, the difference in the weighted mean coefficients of variation being $4.28 \pm .70$ per cent, a difference large enough to be regarded as safely beyond fluctuations of sampling. Also mothers show a greater range in mean age at death than fathers, the extremes being 53.29 years and 73.33 years, giving a range of 20.04 years. Just as for fathers and grandfathers, mothers appear to have a much greater range in mean ages at death than grandmothers, though here again the available data are too meager to permit any definite conclusions. But for what little it is worth, the range for grandmothers in Table 17 is 10.02 years.

3. Both the unweighted and the weighted mean ages for sections A and B of Table 17 give a higher mean age at death for fathers than for mothers. The differences are small, so small in fact as to be statistically without significance. But the difference, if taken at its face value, contradicts one of the most firmly grounded generalizations of biostatistics, namely that women are generally longer-lived than men. And in so doing it reflects on either (a) the reliability (for the purpose to

TABLE 17
Biometric Constants for Age at Death of Various Ancestors
A. Fathers

ITEM NO.	AUTHORITY	NATURE AND SOURCE OF MATERIAL	KIND OF PEOPLE	N	MEAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
1	Pearl, this study, Table 15	Fathers of nonagenarians and centenarians	Chiefly American	365	72.42 ± .60	16.86 ± .42	23.28 ± .61
2	Stoessiger, ⁸⁶ Table I	Pearson Family Data. Accidents and infections omitted. Fathers of sons.....	British	892 ⁸¹	71.33 ± .29	12.87 ± .21	18.04 ⁸⁸
3	Pearl, ⁸⁴ Table 2	Fathers of persons living at age of 90 and over. Nonaccidental causes of death.....	American	37	71.15 ± 2.01	.....	.....
4	Stoessiger, ⁸⁶ Table I	Pearson Family Data. Inclusive. Fathers of sons.....	British	1032 ⁸¹	70.47 ± .28	13.40 ± .20	19.02 ⁸⁸
5	Stoessiger, ⁸⁶ Table I	Pearson Family Data. Inclusive. Fathers of daughters...	British	911 ⁸¹	69.90 ± .31	13.98 ± .22	19.99 ⁸⁸
6	Pearl, ⁸⁶ Table VII	Family History Records. Fathers of selected noncancerous persons	Urban American	120	69.83 ± .97	15.76 ± .69	22.57 ⁸⁸
7	Beeton and Pearson, ⁸⁹ Table A ...	Quaker genealogies. Fathers of adult daughters.....	British	1156 ⁸¹	69.55 ± .27	13.66 ± .19	19.65 ⁸⁸
8	Beeton and Pearson, ⁸⁹ Table A ...	Quaker genealogies. Fathers of adult sons	British	1000 ⁸¹	68.37 ± .31	14.70 ± .22	21.50 ⁸⁸
9	Wilson and Doering, ⁸⁷ p. 428	Peirce Genealogy. Fathers with consort's age at death known..	American	135	68.0 ± 1.3	.....	.....

TABLE 17—Continued
A. Fathers—Continued

ITEM NO.	AUTHORITY	NATURE AND SOURCE OF MATERIAL	KIND OF PEOPLE	N	MEAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
10	Beeton and Pearson, ²⁷ p. 298	Landed Gentry. Fathers of sons dying at 50 years and over	British	? ²¹	66.88	14.33	21.42 ²²
11	Beeton and Pearson, ²⁷ p. 298	Peerage. Fathers of sons dying at 52.5 years and over.	British	? ²¹	66.68	14.67	22.01 ²²
12	Pearl, ²³ Table VII	Family History Records. Fathers of cancerous persons	Urban American	120	66.33± .90	14.66± .64	22.10 ²²
13	Wilson and Doering, ²⁷ p. 428	Peirce Genealogy. All fathers	American	187	66.2 ± 1.1	.....	.....
14	Beeton and Pearson, ²⁷ p. 297	Landed Gentry. Fathers of sons dying at 20 yrs. and over	British	1000 ²¹	65.96	14.43	21.88 ²²
15	Beeton and Pearson, ²⁷ p. 297	Peerage. Fathers of sons dying at 25 years and over.	British	1000 ²¹	65.84	14.64	22.23 ²²
16	Beeton, Yule and Pearson, ²⁸ Table IV	Burke's Landed Gentry. Fathers weighted with their fertility	British	5336 ³⁰	65.51	.....	.....
17	Bell, ³¹ p. 50	Hyde Genealogy	American	795	65.0	.....	.....
18	Beeton and Pearson, ²⁰ Table A	Quaker genealogies. Fathers of minor sons	British	943 ²¹	63.85± .33	15.18± .24	23.78 ²²
19	Beeton, Yule and Pearson, ²⁸ Table I	Burke's Landed Gentry. Age at death of father, correlated with size of family.	British	1000	63.58	15.19	23.88 ²²
20	Beeton and Pearson, ²⁰ Table A	Quaker genealogies. Fathers of minor daughters	British	853 ²¹	63.57± .37	15.84± .26	24.92 ²²

TABLE 17—Continued
A. Fathers—Continued

21	Pearl, ²⁰ Table III	Family History Records. Fathers of selected dead nontuberculous persons	Urban American	504	63.51 ± .48	16.07 ± .34	25.30 ²²
22	Beeton, Yule, and Pearson, ²⁰ Table IV	Whitney Genealogy chiefly. Fathers weighted with their fertility	American	5928 ²⁰	63.08	.....	.....
23	Pearl, ²⁰ Table III	Family History Records. Fathers of dead tuberculous persons	Urban American	504	61.35 ± .49	16.32 ± .35	26.60 ²²
24	Gould, ²⁰ Fig. 1 ...	Genealogical material. "Fathers not grandfathers"	American	? (ca. 50)	60.68 ± 1.56	.....	.....
25	Pearl, this paper, Table 15	Fathers in FHR Series.....	Urban American	143	60.10 ± .87	15.37 ± .61	25.57 ± 1.08
26	Beeton, Yule, and Pearson, ²⁰ Table I	Whitney Genealogy chiefly. Age at death of fathers correlated with size of family.....	American	1084	58.09	16.07	27.66 ²²
27	Pearl, ²⁰ Table III	Family History Records. Fathers of selected living nontuberculous persons	Urban American	180	57.17 ± .81	16.05 ± .57	28.07 ²²
28	Pearl, ²⁰ Table III	Family History Records. Fathers of living tuberculous persons	Urban American	180	54.33 ± .75	14.95 ± .53	27.52 ²²
29	Unweighted averages for fathers, including all (and only) cases for which <i>N</i> , mean, and S.D. are given.....			683.5	65.03 ± .39	15.05 ± .27	23.15 ± .44
30	Weighted averages for fathers, including all (and only) cases for which <i>N</i> , mean, and S.D. are given.....			12,987 ²²	65.91 ± .38	14.78 ± .27	22.43 ± .43

BIOMETRICAL COMPARISONS

TABLE 17—Continued
B. Mothers

ITEM NO.	AUTHORITY	NATURE AND SOURCE OF MATERIAL	KIND OF PEOPLE	N	MEAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
31	Pearl, this study, Table 15	Mothers of nonagenarians and centenarians	Chiefly American	365	73.33±.64	18.03±.45	24.59±.65
32	Pearl, ²⁴ Table 2 ..	Mothers of persons living at ages of 90 and over. Non-accidental causes of death....	American	44	72.73±1.73	.....	.....
33	Stoessiger, ²⁶ Table I	Pearson Family Data. Inclusive. Mothers of daughters	British	796 ²¹	71.72±.34	14.26±.24	19.88 ²²
34	Stoessiger, ²⁶ Table I	Pearson Family Data. Accidents and infections omitted. Mothers of sons	British	819 ²¹	70.86±.36	15.19±.25	21.44 ²²
35	Stoessiger, ²⁶ Table I	Pearson Family Data. Inclusive. Mothers of sons	British	916 ²¹	70.57±.34	15.22±.24	21.56 ²²
36	Beeton and Pearson, ²⁰ Table A ...	Quaker genealogies. Mothers of adult daughters	British	1064 ²¹	68.70±.34	16.42±.24	23.90 ²²
37	Beeton and Pearson, ²⁰ Table A ...	Quaker genealogies. Mothers of adult sons	British	1220 ²¹	67.95±.33	16.90±.23	24.88 ²²
38	Pearl, ²⁸ Table VII	Family History Records. Mothers of cancerous persons....	Urban American	107	67.71±1.07	16.36±.75	24.16 ²²
39	Pearl, ²⁸ Table VII	Family History Records. Mothers of selected noncancerous persons	Urban American	107	67.52±.83	12.69±.59	18.79 ²²

TABLE 17—Continued
B. Mothers—Continued

40	Pearl, ²⁸ Table IV..	Family History Records. Mothers of selected dead nontuberculous persons	Urban American	424	64.72±.52	15.96±.37	24.66 ²⁸
41	Beeton, Yule, and Pearson, ²⁸ Table IV	Quaker genealogies. Mothers weighted with their fertility..	British	6020 ²⁸	63.84	.....	.....
42	Wilson and Doering, ²⁷ p. 428	Peirce Genealogy. Mothers with consort's age at death known	American	135	63.0 ±1.7	.....	.....
43	Gould, ²⁸ Fig. 1 ...	Genealogical material. "Mothers not grandmothers"	American	? (ca. 50)	62.96±1.77	.....	.....
44	Wilson and Doering, ²⁷ p. 428	Peirce Genealogy. All mothers	American	188	61.7 ±1.4	.....	.....
45	Beeton, Yule and Pearson, ²⁸ Table I	Quaker genealogies. Age at death of mothers correlated with size of family.....	British	1036	61.18	18.85	30.80 ²⁸
46	Bell, ²¹ p. 50	Hyde Genealogy	American	671	60.8	.....	.....
47	Beeton, Yule, and Pearson, ²⁸ Table IV	Whitney Genealogy. Mothers weighted with their fertility..	American	5776 ²⁸	59.92	.....	.....
48	Pearl, ²⁸ Table IV..	Family History Records. Mothers of dead tuberculous persons	Urban American	424	58.87±.60	18.17±.42	30.86 ²⁸
49	Beeton and Pearson, ²⁸ Table A ...	Quaker genealogies. Mothers of minor sons	British	795 ²¹	58.60±.43	18.14±.31	30.97 ²¹
50	Beeton and Pearson, ²⁸ Table A ...	Quaker genealogies. Mothers of minor daughters	British	782 ²¹	57.66±.45	18.50±.32	32.08 ²¹

TABLE 17—Continued
B. Mothers—Continued

ITEM NO.	AUTHORITY	NATURE AND SOURCE OF MATERIAL	KIND OF PEOPLE	N	MEAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
51	Pearl, this study, Table 15	Mothers in FHR Series	Urban American	143	55.56±1.04	18.39±.73	33.10±1.46
52	Pearl, ²⁸ Table IV..	Family History Records. Mothers of living tuberculous persons	Urban American	154	54.55±.81	14.94±.57	27.39 ²³
53	Pearl, ²⁸ Table IV..	Family History Records. Mothers of selected living nontuberculous persons	Urban American	154	54.42±.90	16.47±.63	30.26 ²²
54	Beeton, Yule, and Pearson, ²⁸ Table I	Whitney Genealogy. Age at death of mother correlated with size of family	American	1095	53.29	20.46	38.38 ²²
55	Unweighted averages for mothers, including all (and only) cases for which <i>N</i> , mean, and S.D. are given.			611.8	63.37±.46	16.76±.32	26.45±.54
56	Weighted averages for mothers, including all (and only) cases for which <i>N</i> , mean, and S.D. are given.			10,401 ⁸⁸	64.18±.47	17.14±.33	26.71±.55

TABLE 17—Continued
C. Grandfathers

57	Pearl, this study, Table 15	Paternal grandfathers of nonagenarians and centenarians...	Chiefly American	365	76.75± .56	15.73± .39	20.49± .53
58	Pearl, this study,	All grandfathers of nonagenarians and centenarians ⁸⁸	Chiefly American	730	76.25± .39	15.69± .28	20.58± .38
59	Pearl, this study, Table 15	Maternal grandfathers of nonagenarians and centenarians...	Chiefly American	365	75.74± .55	15.64± .39	20.65± .54
60	Gould, ⁸⁸ Fig. 1 ..	Genealogical material. Grandfathers	American	1157	70.98± .25	.....	.....
61	Wilson and Doering, ⁸⁷ p. 429	Peirce Genealogy. Grandfathers weighted with number of sons	American	54	70.5	.....	.....
62	Wilson and Doering, ⁸⁷ p. 429	Peirce Genealogy. Grandfathers unweighted	American	54	69.5	.....	.....
63	Pearl, this study, Table 15	Paternal grandfathers in FHR Series	Urban American	143	68.99± .92	16.35± .65	23.70± 1.00
64	Pearl, this study,	All grandfathers in FHR Series ⁸⁸	Urban American	286	68.57± .65	16.38± .47	23.89± .72
65	Pearl, this study, Table 15	Maternal grandfathers in FHR Series	Urban American	143	68.15± .93	16.40± .65	24.07± 1.01

TABLE 17—Continued
D. Grandmothers

ITEM NO.	AUTHORITY	NATURE AND SOURCE OF MATERIAL	KIND OF PEOPLE	N	MEAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
66	Pearl, this study, Table 15	Paternal grandmothers of nonagenarians and centenarians..	Chiefly American	365	77.05± .56	15.87± .40	20.60± .54
67	Pearl, this study,	All grandmothers of nonagenarians and centenarians ⁸⁶	Chiefly American	730	76.78± .39	15.65± .28	20.39± .37
68	Pearl, this study, Table 15	Maternal grandmothers of nonagenarians and centenarians...	Chiefly American	365	76.51± .54	15.43± .39	20.16± .52
69	Gould, ²⁶ Fig. 1...	Genealogical material. Grandmothers	American	872	70.33± .32	.....	.....
70	Pearl, this study, Table 15	Paternal grandmothers in FHR Series	Urban American	143	70.10± .93	16.55± .66	23.61± .99
71	Pearl, this study,	All grandmothers in FHR Series ⁸⁶	Urban American	286	68.57± .67	16.89± .48	24.63± .74
72	Pearl, this study, Table 15	Maternal grandmothers in FHR Series	Urban American	143	67.03± .96	17.08± .68	25.48± 1.07

²¹ Beeton, M., and Karl Pearson. On the inheritance of the duration of life, and on the intensity of natural selection in man. *Biometrika*, Vol. 1, pp. 50-89, 1901.

²² These numbers apparently do not represent the actual numbers of different ancestors. They are the number of *pairs* of entries in correlation tables. But since each ancestor (father or mother) was presumably entered once for each son (or daughter) the actual number of *different* fathers (or mothers) involved is much smaller than the N given. In the original paper there is nowhere a clear statement to be found as to exactly how many different ancestors are involved. If they are weighted with fertility the biometric constants for ancestors (fathers and mothers) cannot be precisely or critically interpreted. They do not mean the same thing as do the corresponding constants calculated in the usual way, where each individual is counted but once in computing the mean and standard deviation of the sample. Personally the present authors are unable to regard the means, standard deviations, and coefficients of variation for age at death of fathers or mothers, as apparently computed in the studies by Pearson and his co-workers, as having any real *biological* meaning whatsoever. They appear to us to be merely numerical by-products of the computations of correlation coefficients. They may or may not differ significantly from the true means, standard deviations, etc. of the samples of fathers and mothers actually used. No one knows; at least no one is told. We include them here merely because we are bringing together in Table 17, as completely as we are able, all the published material bearing on the subject. How different the mean longevity of parents *may be* when computed with and without fertility weighting is seen in comparing item 26 (unweighted) with item 22 (weighted), item 19 (unweighted) with item 16 (weighted), item 54 (unweighted) with item 47 (weighted), and item 45 (unweighted) with item 41 (weighted) in Table 17.

²³ Computed from original mean and standard deviation by present authors, using all decimals tabulated in original.

²⁴ Pearl, R. The age at death of the parents of the tuberculous and the cancerous. *Amer. Jour. Hyg.*, Vol. 3, pp. 71-89, 1923.

²⁵ Pearl, R. Preliminary account of an investigation of factors influencing longevity. *Jour. Amer. Med. Assoc.*, Vol. 82, pp. 259-264, 1924.

²⁶ Gould, Alice. The longevity of grandparents. *Eug. News*, Vol. 12, pp. 166-171; 175-178, 1927.

²⁷ Stoessiger, Brenda. On the inheritance of duration of life and cause of death. *Ann. Eug.*, Vol. 5, pp. 105-178, 1933.

²⁸ Beeton, M., and K. Pearson. Data for the problem of evolution in man. II. A first study of the inheritance of longevity and the selective death-rate in man. *Proc. Roy. Soc.*, Vol. 65, pp. 290-305, 1899.

²⁹ Beeton, M., G. U. Yule, and K. Pearson. Data for the problem of evolution in man. V. On the correlation between duration of life and the number of offspring. *Proc. Roy. Soc.*, Vol. 67, pp. 159-179, 1900.

³⁰ This is the total number of father-offspring pairs. The actual number of fathers was 1084, as given in item 24. Cf. footnote 21.

³¹ This is the total number of father-offspring pairs. The actual number of fathers was 1000, as given in item 17. Cf. footnote 21.

³² Bell, A. G. The Duration of Life and Conditions associated with Longevity. A Study of the Hyde Genealogy. *Washington* (Genealogical Record Office) 1918. Pp. 57.

³³ This is the sum of the recorded N 's of the samples averaged. But in computing the probable errors the average N (683.5) was used. See also footnote 21. The use of the mean N for the probable errors is conservative, but considering the heterogeneous character of the groups averaged the resulting probable errors certainly do not overstate our confidence in the combined results.

³⁴ This is the total number of mother-offspring pairs. The actual number of mothers was 1095, as given in item 50. Cf. footnote 21.

³⁵ This is the total number of mother-offspring pairs. The actual number of mothers was 1036, as given in item 41. Cf. footnote 21.

³⁶ This is the sum of the recorded N 's of the samples averaged. But in computing the probable errors the average N (611.8) was used. See also footnotes 21 and 32.

³⁷ Constants computed from combined frequency distributions.

³⁸ Wilson, Edwin B., and C. R. Doering. The elder Peirces. *Proc. Nat. Acad. Sci.*, Vol. 12, pp. 424-432, 1926.

which they have been put) of the basic materials of the studies from the results of which Table 17 has been built up, or (b) the adequacy and validity of the biometric methods used in the analysis of those materials, or (c) some combination of both (a) and (b). In an earlier paper Pearl⁸ has presented evidence warranting grave doubt as to (b) insofar as relates to the correlational technique, and various writers have presented criticisms along the line of (a). Further evidence for scepticism as to the adequacy of conventional biometric methods in the premises will appear as we proceed in the present study.

CHAPTER XI

ACTUARIAL COMPARISONS



AS HAS been said Table 17 presents the pertinent available evidence regarding the ages at death of parents and grandparents that has been derived by the application of conventional biometric methods to the data. But besides this there is a certain amount of material pertinent to the problem derived by the application of actuarial methods to essentially the same *kind* of raw data. This material will now be presented in Table 18. To this table is also added an extensive compilation of life table data regarding the average duration of life of male and female human beings generally, which it is hoped will be found useful in various connections.

Wherever possible three columns of numerical data are presented in Table 18, namely $\dot{e}_{15} + 15$, $\dot{e}_{20} + 20$, and $\dot{e}_{30} + 30$. That is, the expectation of life (mean after lifetime) at ages 15, 20 and 30 years, plus the 15, 20, and 30 years respectively lived up to the times of stated expectations. The reason for the choice of these years is that persons who achieve the status of parents first do so, in the vast majority of cases, somewhere between the ages of 15 and 30 years. They have, as individuals, certainly lived that long. The primary purpose of including the figures from general population life tables is to help towards the formation of a judgment on an important question. Do parents (or grandparents) live longer by virtue of (or in association with) their parenthood than do actuarially comparable people in general, that is, people who have lived at least as long as the ages at which persons achieve the status of parenthood?

Inasmuch as a great range of life table data is presented in Table 18, derived from a variety of different kinds of observational material, and since the meaning of the actuarial statistic "expectation of life" (\dot{e}_x) differs somewhat according to the material upon which the life table is based from which it is derived, it seems advisable to make a few precautionary explanations. In Table 18 are included data from life tables computed from five more or less different kinds of raw material, viz. (1) genealogies where only the dead are used, (2) genealogies where both living and dead are used, (3) family history records got by per-

sonal interviews with a considerable fraction of the persons involved, where both dead and living are used, (4) records of births, deaths, and total populations in a general population, and (5) the experience of life insurance companies with their policy holders.

Now in the case of (1) each individual is followed throughout his life, and has complete opportunity to live his life out. The expectation of life computed from such material is the actual average number of years lived by the persons involved, after the stated age. In consequence, with such material, expectation of life at birth and mean age at death are identical for the same population.

Under case (4) the expectation of life has not this same direct and clear meaning, because when life tables are constructed from the census (population) and registration (births and deaths) data, the age specific life table death rates (q_x), from which all other life table functions are derived, appertain solely to the forces of natality and mortality for the single year (or short period of years) for which the table is calculated. But in calculating the derived constants, and particularly the expectation of life, the assumption is tacitly made that these particular specific deaths operate (at the respective ages) throughout the life times of the individuals involved in the table. Now this may or may not be the fact; or, better stated, the actuality may deviate from this postulated state of affairs in a variety of directions and degrees. Insofar as it does so deviate expectation of life at birth will tend to deviate from the mean age at death of the persons actually involved in the table.

Cases (2) and (3) will fall in an intermediate position between (1) and (4), the expectation of life being in any case a less theoretical sort of figure than in (4), and approaching more and more to the precise meaning it has in (1) as the living persons included rise in age. It is actually a weighted average of the ages at death of the dead, and the expectations of life of those living at the time of record.

Life tables constructed from the experience of life insurance companies (5) fall essentially in the same position as (2) and (3). They differ theoretically only because of two complicating factors; namely variable age at entrance into the experience, instead of uniform entrance at birth as in (2) and (3), and lapses of policies (withdrawal from the experience from causes other than death). In a large enough experience the effect of these complicating factors is not serious, or to put it more precisely, may be adequately corrected.

TABLE 18
Life Table Data on Duration of Life of (a) Ancestors, and (b) General and Special Populations
A. Fathers

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
1	Pearl, ⁹ p. 263.....	FHR data. Fathers of persons dying at 80 and over .....	...	78.5	79.8 ⁸⁸
2	Pearl, ⁹ p. 257.....	FHR data. Fathers of persons dying at 50 and over .....	...	70.4	70.8 ⁸⁸
3	Pearl, ⁹ p. 263.....	FHR data. Fathers of persons dying under 5 .....	...	66.3	67.5 ⁸⁸
4	Pearl, ⁹ p. 257.....	FHR data. Fathers of persons dying under 50 .....	...	66.1	67.2 ⁸⁸
5	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Fathers of sons dying 70 and over years of age .....	...	62.7	63.9
6	Gould, ²⁸ p. 176	Genealogical data. Parents not grandparents, born 1775-1824 .....	...	...	63.2
7	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Fathers of sons dying 50-69 years of age .....	...	60.9	62.2
8	Pearl, ⁹ Table XXX	Genealogical data .....	...	...	71.1
9	Yuan, ^{87a} Table 5	Genealogy of a southern Chinese family. All fathers of sons living 20 or more years .....	...	59.6	61.0
10	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Fathers of sons dying 20-40 years of age .....	...	59.0	60.4
11	Unweighted means	Fathers .....	...	65.44	66.71

ACTUARIAL COMPARISONS

TABLE 18—Continued
B. Mothers

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
12	Pearl, ⁸ p. 264	FHR data. Mothers of persons dying at 80 and over	...	82.6	82.6 ⁸⁸
13	Pearl, ⁸ p. 258	FHR data. Mothers of persons dying at 50 and over	...	71.6	74.6 ⁸⁸
14	Pearl, ⁸ p. 264	FHR data. Mothers of persons dying under 5	...	69.1	71.3 ⁸⁸
15	Pearl, ⁸ p. 258	FHR data. Mothers of persons dying under 50	...	68.3	70.3 ⁸⁸
16	Pearl, ⁹ Table XXXI	Genealogical data	...	...	69.9
17	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Mothers of sons dying 70 and over years of age	...	64.6	66.6
18	Gould, ²⁵ p. 176	Genealogical data. Parents not grandparents, born 1775-1824	...	63.7	67.2
19	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Mothers of sons dying 50-69 years of age	...	63.6	65.2
20	Yuan, ^{87a} Table 5	Genealogy of a southern Chinese family. All mothers of sons living 20 or more years	...	61.3	63.3
21	Yuan, ^{87a} Table 8	Genealogy of a southern Chinese family. Mothers of sons dying 20-49 years of age	...	60.5	62.3
22	Unweighted means	Mothers	...	67.26	69.33

TABLE 18—Continued

C. Grandfathers

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
23	Pearl, ^a p. 259	FHR data. Grandfathers of persons dying at 50 and over	...	70.6	72.2 ⁸⁸
24	Gould, ²⁸ p. 176	Genealogical data. Grandfathers born 1775-1824	...	...	71.6
25	Pearl, ^a p. 259	FHR data. Grandfathers of persons dying under 50	...	67.2	67.9 ⁸⁸
26	Unweighted means	Grandfathers	...	68.90	70.57

D. Grandmothers

27	Pearl, ^a p. 260	FHR data. Grandmothers of persons dying at 50 and over	...	77.4	79.9 ⁸⁸
28	Gould, ²⁸ p. 176	Genealogical data. Grandmothers born 1775-1824	...	70.8	71.3
29	Pearl, ^a p. 260	FHR data. Grandmothers of persons dying under 50	...	68.8	70.1 ⁸⁸
30	Unweighted means	Grandmothers	...	72.33	73.77

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TABLE 18—Continued
E. General and Special Populations
I. Males

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
31	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1921-1925 .....	.....	69.40	70.80
32	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1921-1922 .....	.....	68.66	69.98
33	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1921-1925 .....	.....	68.49	70.66
34	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1911-1915 .....	.....	67.61	69.03
35	Inst. Int. de Statistique, ⁸⁹ p. 446	Saxony, 1924-1926 .....	.....	67.43	69.02
36	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1906-1910 .....	.....	67.20	68.78
37	Inst. Int. de Statistique, ⁸⁹ p. 449	Australia, 1920-1922 .....	.....	66.99	68.44
38	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1901-1905 .....	.....	66.74	68.47
39	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1924-1926 .....	.....	66.72	68.68
40	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1910-1920 .....	.....	66.70	68.80
41	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1924-1926 .....	.....	66.70	68.56
42	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1911-1915 .....	.....	66.70	68.40
43	Inst. Int. de Statistique, ⁸⁹ p. 446	Bavaria, 1924-1926 .....	.....	66.60	68.13
44	DePorte, ⁴⁰ p. 306	New York State, 1910. Native whites of native parentage .....	.....	66.57	68.31
45	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1896-1900 .....	.....	66.34	67.19
46	Glover ⁷ p. 216	Denmark, 1906-1910	65.5	66.3	68.0
47	Inst. Int. de Statistique, ⁸⁹ p. 449	Union of South Africa, 1925-1927 Euro- peans .....	.....	66.27	67.87
48	Inst. Int. de Statistique, ⁸⁹ p. 448	White Russia, 1926-1927 .....	.....	66.22	68.58
49	Bull. Met. Life Ins. Co., ⁴⁶ p. 8	American physicians. White. 1925 .....	.....	.....	68.01
50	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1916-1920 .....	.....	66.10	68.90
51	Glover, ⁷ p. 112	U. S. A. Original Registration States. 1901. Whites in rural parts	65.01	65.97	68.37

52	Glover, ⁷ p. 232	American-Canadian Mortality Investigation, 1900-1915	65.06	65.93	67.70
53	Glover, ⁷ p. 114	U. S. A. Original Registration States. 1910. Whites in rural parts	65.10	65.92	68.10
54	Glover, ⁷ p. 216	Sweden, 1901-1910	64.79	65.88	68.57
55	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1920-1922	....	65.78	67.40
56	Glover, ⁷ p. 216	Holland, 1900-1909	64.8	65.7	67.8
57	Inst. Int. de Statistique, ⁸⁹ p. 448	North Ireland, 1925-1927	....	65.63	67.46
58	Glover, ⁷ p. 232	Seventeen Swedish Offices Life Tables, 1895-1906	64.01	65.59	66.99
59	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1891-1895	....	65.47	67.54
60	Dublin, Kopf, and Lotka, ⁴⁸ p. 330	U. S. Registration Area. 1922. Whites ..	64.59	65.42	67.31
61	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1901-1905	....	65.40	67.40
62	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1911-1920	....	65.27	68.57
63	Inst. Int. de Statistique, ⁸⁹ p. 449	Union of South Africa, 1920-1922. Europeans	....	65.26	67.08
64	Inst. Int. de Statistique, ⁸⁹ p. 447	Italy, 1921-1922	....	65.17	67.67
65	Glover, ⁷ p. 216	Norway, 1901-1910	63.69	65.16	68.86
66	Bull. Met. Life Ins. Co., ⁴⁴ p. 7	U. S. Registration Area. 1919-1920. Whites	64.04	64.94	67.14
67	Inst. Int. de Statistique, ⁸⁹ p. 449	Siberia (U. R. S. S.), 1926-1927	....	64.86	67.29
68	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1911-1920	....	64.85	68.83
69	Dublin, ⁴⁹ p. 96	Russian born whites (mostly Jews) living in New York State, 1910	....	64.84	....
70	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1921	....	64.82	66.52
71	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1891-1900	....	64.75	67.50
72	Glover, ⁷ p. 216	Australia, 1901-1910	64.03	64.74	66.52
73	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukraine, 1926-1927	....	64.58	67.25
74	Gould, ⁸⁸ p. 176	American genealogical population, born 1775-1824	63.81	64.53	67.83
75	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1895-1900	....	64.50	66.80

TABLE 18—Continued
 E. General and Special Populations (Continued)
 I. Males (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	\bar{e}_{15+15} (years)	\bar{e}_{20+20} (years)	\bar{e}_{30+30} (years)
76	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukrainia, 1925-1926 .....	....	64.49	67.18
77	Dublin, ⁴⁹ p. 96	Italian born whites, living in New York State, 1910 .....	....	64.26	....
78	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1910-1912 .....	....	64.21	65.81
79	Inst. Int. de Statistique, ⁸⁹ p. 447	Italy, 1910-1912 .....	....	64.20	66.73
80	Pearl, ⁹ p. 235	FHR data. Moderate drinkers .....	....	....	66.75
81	Pearl, ⁹ p. 235	FHR data. Abstainers .....	....	....	66.34
82	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1881-1890 .....	....	64.18	66.87
83	Jones, ⁴² p. 29	Glasgow, 1909-1912. Four room houses and up	63.54	64.16	....
84	Inst. Int. de Statistique, ⁸⁹ p. 446	Saxony, 1900/01-1910/11 .....	....	64.14	66.02
85	Bull. Met. Life Ins. Co., ⁴³ p. 1	Industrial policy holders. 1921. Whites ..	63.28	64.01	65.74
86	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway. 1881/82-1890/91 .....	....	63.89	67.68
87	Inst. Int. de Statistique, ⁸⁹ p. 448	Switzerland, 1920-1921 .....	....	63.85	65.56
88	Jones, ⁴² p. 29	Glasgow, 1909-1912. Three room houses..	63.06	63.81	....
89	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1885-1894 .....	....	63.60	66.20
90	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1891/92-1900/01 .....	....	63.58	67.69
91	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1911-1914 .....	....	63.46	65.40
92	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1910-1911 .....	....	63.43	65.29
93	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1890-1899 .....	....	63.40	65.90
94	Bull. Met. Life Ins. Co., ⁴³ p. 1	Industrial policy holders. 1930. Whites ...	62.79	63.35	64.75
95	Glover, ⁷ p. 90	U. S. A. Original Registration States. 1910. Native whites	62.52	63.32	65.61
96	Glover, ⁷ p. 216	Italy, 1901-1910	62.17	63.27	65.94

97	Inst. Int. de Statistique, ⁹⁹ p. 447	Scotland, 1911 .....	....	63.27	65.17
98	Glover, ⁷ p. 88	U. S. A. Original Registration States, 1901. Native whites	62.28	63.24	66.08
99	Inst. Int. de Statistique, ⁹⁹ p. 448	U. R. S. S. European Russia, 1926-1927 ..	....	63.24	65.65
100	Inst. Int. de Statistique, ⁹⁹ p. 446	Denmark, 1880-1889 .....	....	63.20	65.90
101	Inst. Int. de Statistique, ⁹⁹ p. 447	Norway, 1856-1865 .....	....	63.16	66.28
102	Inst. Int. de Statistique, ⁹⁹ p. 447	Norway, 1871/72-1880/81 .....	....	63.14	66.82
103	Inst. Int. de Statistique, ⁹⁹ p. 446	Bavaria, 1911-1913 .....	....	63.11	64.93
104	Inst. Int. de Statistique, ⁹⁹ p. 447	Italy, 1899-1902 .....	....	63.10	65.65
105	Glover, ⁷ p. 232	Thirty American Offices Life Tables, 1874	61.57	63.07	65.85
106	Glover, ⁷ p. 216	England, 1901-1910	62.31	63.01	64.76
107	Inst. Int. de Statistique, ⁹⁹ p. 447	France, 1920-1923 .....	....	62.93	65.50
108	Inst. Int. de Statistique, ⁹⁹ p. 446	Wurtemberg, 1901-1910 .....	....	62.93	64.94
109	Inst. Int. de Statistique, ⁹⁹ p. 448	Ukraine, 1924 .....	....	62.84	....
110	Inst. Int. de Statistique, ⁹⁹ p. 449	Australia, 1891-1900 .....	....	62.81	65.11
111	Inst. Int. de Statistique, ⁹⁹ p. 446	Prussia, 1906-1910 .....	....	62.81	64.75
112	Glover, ⁷ p. 68	U. S. A. Original Registration States, 1910. Whites	61.91	62.71	64.87
113	Glover, ⁷ p. 216	Germany, 1901-1910	61.71	62.56	64.55
114	Inst. Int. de Statistique, ⁹⁹ p. 448	Russian Soc. Fed. Sov. Rep., 1926-1927 ...	....	62.48	64.82
115	Glover, ⁷ p. 58	U. S. A. Original Registration States, 1910	61.66	62.48	64.70
116	Glover, ⁷ p. 232	British Offices Life Tables. 1863-1893. O ^{M(5)}	60.98	62.39	65.06
117	Glover, ⁷ p. 66	U. S. A. Original Registration States, 1901- 1910. Whites	61.50	62.39	64.80
118	Inst. Int. de Statistique, ⁹⁹ p. 447	Holland, 1880-1889 .....	....	62.30	65.10
119	Inst. Int. de Statistique, ⁹⁹ p. 448	Sweden, 1871-1880 .....	....	62.30	65.10
120	Inst. Int. de Statistique, ⁹⁹ p. 448	White Russia, 1896-1897 .....	....	62.23	64.82
121	Dublin, ⁴⁹ p. 96	English, Scotch and Welsh born whites, living in New York State, 1910 .....	....	62.23	....
122	Glover, ⁷ p. 232	American Experience Mortality Tables, 1860	60.50	62.20	65.33

TABLE 18—Continued
 E. General and Special Populations (Continued)
 I. Males (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15} + 15$ (years)	$\dot{e}_{20} + 20$ (years)	$\dot{e}_{30} + 30$ (years)
123	Jones, ⁴² p. 41	Glasgow, 1920-1922	61.38	62.20	63.92
124	Glover, ⁷ p. 64	U. S. A. Original Registration States, 1901. Whites	61.25	62.19	64.88
125	Inst. Int. de Statistique, ⁸⁹ p. 447	Finland, 1901-1910	.....	62.16	64.94
126	Glover, ⁷ p. 56	U. S. A. Original Registration States, 1901	61.06	62.03	64.76
127	Inst. Int. de Statistique, ⁸⁹ p. 446	Bavaria, 1901-1910	.....	61.93	64.01
128	Inst. Int. de Statistique, ⁸⁹ p. 446	Belgium, 1891-1900	.....	61.80	64.20
129	Glover, ⁷ p. 98	U. S. A. Original Registration States, 1910. Foreign-born whites	60.89	61.75	63.71
130	Pearl, ⁹ p. 235	FHR data. All drinkers	.....	.....	63.60
131	Glover, ⁷ p. 216	Switzerland, 1901-1910	60.86	61.70	63.80
132	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukraine, 1895-1898	.....	61.70	.....
133	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1891-1900	.....	61.68	63.95
134	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1860-1869	.....	61.60	64.50
135	Glover, ⁷ p. 216	France, 1898-1903	60.45	61.53	64.35
136	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1900-1901	.....	61.53	63.69
137	Inst. Int. de Statistique, ⁸⁹ p. 447	Iceland, 1901-1910	.....	61.50	65.40
138	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1908-1913	.....	61.39	64.03
139	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1891-1900	.....	61.30	63.52
140	Inst. Int. de Statistique, ⁸⁹ p. 446	Belgium, 1881-1890	.....	61.29	64.06
141	DePorte, ⁴⁰ p. 310	New York State, 1910. Foreign-born whites	.....	61.26	63.08
142	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1891-1900	.....	61.23	63.46
143	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1861-1865	.....	61.20	64.65
144	Jones, ⁴² p. 29	Glasgow, 1909-1912. Two room houses.	60.33	61.19	.....

145	Inst. Int. de Statistique, ⁸⁹ p. 446	Saxony, 1891-1900	61.16	63.08
146	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders. 1911-1916. Whites. Tuberculosis absent	60.5	61.1 62.6
147	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1891-1900	61.02	63.07
148	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1861-1870	61.00	63.60
149	Inst. Int. de Statistique, ⁸⁹ p. 448	U. R. S. S. European Russia, 1896-1897..	60.98	63.78
150	Inst. Int. de Statistique, ⁸⁹ p. 446	Austria, 1906-1910	60.90	63.49
151	Inst. Int. de Statistique, ⁸⁹ p. 446	Bavaria, 1891-1900	60.80	63.13
152	Dublin, ⁴⁹ p. 96	German born whites, living in New York State, 1910	60.80	....
153	Glover, ⁷ p. 96	U. S. A. Original Registration States. 1901. Foreign-born whites	59.71	60.68 63.07
154	Inst. Int. de Statistique, ⁸⁹ p. 448	Russian Soc. Fed. Sov. Rep., 1896-1897 ...	60.60	63.37
155	Inst. Int. de Statistique, ⁸⁹ p. 449	Australia, 1881-1890	60.58	63.64
156	Glover, ⁷ p. 106	U. S. A. Original Registration States, 1910. Whites in cities	59.72	60.51 62.61
157	Inst. Int. de Statistique, ⁸⁹ p. 446	Austria, 1901-1905	60.50	63.27
158	Inst. Int. de Statistique, ⁸⁹ p. 448	Switzerland, 1889-1900	60.50	62.90
159	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1877-1881	60.42	63.83
160	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1891-1900	60.36	62.95
161	Inst. Int. de Statistique, ⁸⁹ p. 447	Italy, 1876-1887	60.35	63.50
162	Glover, ⁷ p. 216	Japan, 1898-1903	59.02	60.35 63.44
163	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1870-1879	60.30	63.70
164	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1881-1890	60.27	62.52
165	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1881-1890	60.19	63.06
166	Inst. Int. de Statistique, ⁸⁹ p. 446	Austria, 1895-1900	60.17	63.03
167	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1890-1891	60.07	62.50
168	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1817-1831	60.00	64.00
169	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1876-1880	60.00	62.80

TABLE 18—Continued
 E. General and Special Populations (Continued)
 I. Males (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
170	Inst. Int. de Statistique, ³⁹ p. 448	Sweden, 1856-1860 .....	....	59.99	62.91
171	Inst. Int. de Statistique, ³⁹ p. 446	Denmark, 1835-1844 .....	....	59.80	62.60
172	Inst. Int. de Statistique, ³⁹ p. 448	Switzerland, 1881-1888 .....	....	59.58	62.21
173	Inst. Int. de Statistique, ³⁹ p. 446	Germany, 1881-1890 .....	....	59.52	62.11
174	Inst. Int. de Statistique, ³⁹ p. 447	England and Wales, 1838-1854 .....	....	59.48	62.76
175	Inst. Int. de Statistique, ³⁹ p. 447	England and Wales, 1871-1880 .....	....	59.40	62.10
176	Bull. Met. Life Ins. Co., ⁴³ p. 1	Industrial policy holders, 1921. Colored ...	58.06	59.24	62.17
177	DePorte, ⁴⁰ p. 308	New York State. 1910. Native white of foreign or mixed parentage .....	....	59.20	61.93
178	Glover, ⁷ p. 104	U. S. A. Original Registration States. 1901. Whites in cities	58.15	59.13	61.89
179	Inst. Int. de Statistique, ³⁹ p. 449	Japan, 1921-1925 .....	....	59.10	62.59
180	Jones, ⁴² p. 29	Glasgow, 1909-1912. One room house....	57.99	58.98	....
181	Inst. Int. de Statistique, ³⁹ p. 448	Sweden, 1841-1845 .....	....	58.95	61.60
182	Inst. Int. de Statistique, ³⁹ p. 447	Scotland, 1861-1870 .....	....	58.75	62.20
183	Inst. Int. de Statistique, ³⁹ p. 448	Switzerland, 1876-1880 .....	....	58.70	61.70
184	Inst. Int. de Statistique, ³⁹ p. 447	Scotland, 1871-1880 .....	....	58.68	62.05
185	Inst. Int. de Statistique, ³⁹ p. 448	Sweden, 1846-1850 .....	....	58.58	61.18
186	Inst. Int. de Statistique, ³⁹ p. 446	Germany, 1871/72-1880/81 .....	....	58.45	61.41
187	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders, 1911-1916. Colored. Tuberculosis absent	57.2	58.2	60.6
188	Glover, ⁷ p. 232	Three Japanese Offices Life Tables. 1905. J ^{M(5)}	56.15	58.16	61.88
189	Inst. Int. de Statistique, ³⁹ p. 448	Sweden, 1851-1855 .....	....	58.11	60.89

190	Inst. Int. de Statistique, ³⁹ p. 446	Prussia, 1867-1877 .....	....	58.08	61.18
191	Inst. Int. de Statistique, ³⁹ p. 447	Holland, 1850-1859 .....	....	57.95	61.44
192	Inst. Int. de Statistique, ³⁹ p. 447	Finland, 1911-1920 .....	....	57.91	62.49
193	Yuan, ⁴⁷ p. 167	Genealogy of a southern Chinese family. All entries .....	....	57.7	59.6
194	Inst. Int. de Statistique, ³⁹ p. 447	Iceland, 1890-1901 .....	....	57.67	61.66
195	Glover, ⁷ p. 232	American Standard Industrial Mortality Table. 1896-1905	56.55	57.50	60.62
196	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders, 1911-1916. Whites. Tuberculosis present	56.7	57.4	59.8
197	Inst. Int. de Statistique, ³⁹ p. 448	Sweden, 1816-1840 .....	....	57.32	60.25
198	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders. 1911-1912. Whites	56.12	56.87	59.36
199	Inst. Int. de Statistique, ³⁹ p. 446	Austria, 1870-1880 .....	....	56.80	60.53
200	Yuan, ⁴⁷ p. 168	Genealogy of a southern Chinese family. Births between 1700 and 1749 .....	....	56.6	60.0
201	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders. 1930. Colored ..	55.32	56.49	59.55
202	Inst. Int. de Statistique, ³⁹ p. 447	Iceland, 1850-1860 .....	....	56.42	60.63
203	Hernando, ⁴¹ p. 174	Manila, 1920. Native born	54.21	55.69	59.11
204	Pearl, ⁹ p. 235	FHR data. Heavy drinkers .....	....	....	58.57
205	Glover, ⁷ p. 76	Original Registration States, 1901. Negroes	53.26	55.11	59.25
206	Yuan, ⁴⁷ p. 169	Genealogy of a southern Chinese family. Births between 1750 and 1799 .....	....	54.8	57.9
207	Inst. Int. de Statistique, ³⁹ p. 447	Holland, 1840-1851 .....	....	54.62	59.74
208	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders. 1911-1912. Colored	52.42	54.16	57.95
209	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders. 1911-1916. Col- ored. Tuberculosis present	52.1	53.8	57.7
210	Glover, ⁷ p. 78	U. S. A. Original Registration States, 1901- 1910. Negroes	51.98	53.78	57.97
211	Yuan, ⁴⁷ p. 169	Genealogy of a southern Chinese family. Births between 1800-1849 .....	....	53.7	57.4

TABLE 18—Continued
 E. General and Special Populations (Continued)
 I. Males (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\bar{e}_{15}+15$ (years)	$\bar{e}_{20}+20$ (years)	$\bar{e}_{30}+30$ (years)
212	Glover, ^f p. 80	U. S. A. Original Registration States, 1910. Negroes	51.77	53.46	57.33
213	Jones, ⁴² p. 35	Glasgow, 1870-1872	51.57	53.42	56.91
214	Yuan, ⁴⁷ p. 168	Genealogy of a southern Chinese family. Births between 1600 and 1699	....	52.9	57.9
215	Dublin, ⁴⁸ p. 96	Irish born whites, living in New York State, 1910	....	51.35	....
216	Glover, ^f p. 216	India, 1901-1910	45.32	47.46	52.44
217	Unweighted means	Males	59.95	61.75	64.39
<i>II. Females</i>					
218	Inst. Int. de Statistique, ³⁰ p. 449	New Zealand, 1921-1922	....	70.36	71.76
219	Inst. Int. de Statistique, ³⁰ p. 449	Australia, 1920-1922	....	70.03	71.48
220	Inst. Int. de Statistique, ³⁰ p. 448	Sweden, 1921-1925	....	69.73	71.68
221	Jones, ⁴² p. 29	Glasgow, 1909-1912. Four room house and up	69.20	69.62	....
222	Inst. Int. de Statistique, ³⁰ p. 449	Union of South Africa, 1925-1927. Euro- peans	....	69.34	70.77
223	Inst. Int. de Statistique, ³⁰ p. 446	Denmark, 1921-1925	....	69.30	70.80
224	Inst. Int. de Statistique, ³⁰ p. 446	Saxony, 1924-1926	....	69.19	70.73

225	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1911-1915	69.14	70.53
226	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1906-1910	68.77	70.48
227	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1920-1922	68.73	70.26
228	Inst. Int. de Statistique, ⁸⁹ p. 448	White Russia, 1926-1927	68.61	71.79
229	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1911-1915	68.40	70.20
230	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1901-1905	68.23	70.06
231	Glover, ⁷ p. 218	Denmark, 1906-1910	67.4	68.2
232	Inst. Int. de Statistique, ⁸⁹ p. 449	Union of South Africa. 1920-1922. Euro- peans	68.15	69.93
233	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1924-1926	68.09	69.76
234	Inst. Int. de Statistique, ⁸⁹ p. 449	Siberia (U. R. S. S.), 1926-1927	67.98	70.59
235	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1896-1900	67.91	69.72
236	Pearl, ⁹ p. 239	FHR data. Moderate drinkers .....	....	70.95
237	Glover, ⁷ p. 218	Sweden, 1901-1910	66.48	67.66
238	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1924-1926	67.55	69.16
239	Glover, ⁷ p. 218	Australia, 1901-1910	66.86	67.52
240	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1910-1920	67.50	69.50
241	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1901-1905	67.50	66.60
242	Inst. Int. de Statistique, ⁸⁹ p. 448	Russian Soc. Fed. Sov. Rep., 1926-1927 ...	67.48	69.79
243	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1911-1920	67.37	70.18
244	Inst. Int. de Statistique, ⁸⁹ p. 448	U. R. S. S. European Russia, 1926-1927..	67.36	69.75
245	Glover, ⁷ p. 218	Norway, 1901-1910	66.05	67.35
246	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1916-1920	67.20	69.60
247	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1911-1920	67.19	70.35
248	Inst. Int. de Statistique, ⁸⁹ p. 449	New Zealand, 1891-1895	67.19	69.33
249	Inst. Int. de Statistique, ⁸⁹ p. 446	Bavaria, 1924-1926	67.17	68.63
250	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1910-1912	67.10	68.54
251	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders. 1930. Whites ..	66.49	67.01
252	Glover, ⁷ p. 218	Holland, 1900-1909	66.0	66.9

TABLE 18—Continued
 E. General and Special Populations (Continued)
 II. Females (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
253	Glover, ⁷ p. 118	U. S. A. Original Registration States, 1910. Whites in rural parts	66.07	66.86	69.05
254	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1921	....	66.82	68.63
255	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukraine, 1926-1927	....	66.76	69.34
256	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1891-1900	....	66.76	69.31
257	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1895-1900	....	66.70	68.90
258	Dublin, ⁴⁹ p. 96	Russian born whites (mostly Jews), living in New York State. 1910	....	66.60	....
259	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1891/92-1900/01	....	66.54	69.43
260	Inst. Int. de Statistique, ⁸⁹ p. 447	Iceland, 1901-1910	....	66.50	69.40
261	Dublin, Kopf, and Lotka, ⁴⁶ p. 332	U. S. Registration Area, 1922. Whites	65.62	66.44	68.42
262	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1881-1890	....	66.40	68.82
263	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukraine, 1925-1926	....	66.37	69.08
264	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1920-1923	....	66.16	68.61
265	Glover, ⁷ p. 116	U. S. A. Original Registration States, 1901. Whites in rural parts	65.06	66.09	68.80
266	Jones, ⁴² p. 29	Glasgow, 1909-1912. Three room house	65.32	66.00	....
267	Inst. Int. de Statistique, ⁸⁹ p. 447	Italy, 1921-1922	....	65.92	68.33
268	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1881/82-1890/91	....	65.90	68.81
269	Bull. Met. Life Ins. Co., ⁴³ p. 1	Industrial policy holders, 1921. Whites	65.12	65.88	67.74
270	Inst. Int. de Statistique, ⁸⁹ p. 448	Switzerland, 1920-1921	....	65.85	67.79
271	Pearl, ⁹ p. 239	FHR data. Abstainers	....	....	67.63
272	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1911-1914	....	65.81	67.72
273	Bull. Met. Life Ins. Co., ⁴⁴ p. 8	U. S. Registration Area, 1919-1920. Whites	64.94	65.77	68.25

274	Glover, ^f p. 218	England, 1901-1910	65.08	65.77	67.36
275	Glover, ^f p. 94	U. S. A. Original Registration States, 1910. Native whites	64.98	65.76	67.98
276	Inst. Int. de Statistique, ⁸⁹ p. 449	Australia, 1891-1900	....	65.72	67.86
277	Dublin, ⁴⁹ p. 96	German born whites, living in New York State, 1910	....	65.57	....
278	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1885-1894	....	65.40	67.90
279	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1871/72-1880/81	....	65.39	68.19
280	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1910-1911	....	65.35	67.30
281	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1911	....	65.35	67.22
282	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1906-1910	....	65.32	67.29
283	Inst. Int. de Statistique, ⁸⁹ p. 447	Norway, 1856-1865	....	65.27	67.81
284	Inst. Int. de Statistique, ⁸⁹ p. 448	North Ireland, 1925-1927	....	65.22	67.42
285	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1871-1880	....	65.00	67.50
286	Glover, ^f p. 92	U. S. A. Original Registration States. 1901. Native whites	63.96	64.97	67.81
287	Gould, ²⁸ p. 176	American genealogical population, born 1775-1824	64.16	64.96	68.12
288	Dublin, ⁴⁹ p. 96	Italian born whites, living in New York State, 1910	....	64.94	....
289	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1880-1889	....	64.90	67.60
290	Glover, ^f p. 74	U. S. A. Original Registration States, 1910. Whites	64.12	64.88	66.96
291	Glover, ^f p. 218	Germany, 1901-1910	64.00	64.84	66.94
292	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1908-1913	....	64.83	67.67
293	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1890-1899	....	64.80	67.10
294	Dublin and Whitney, ⁴⁸ p. 442	Industrial policy holders, 1911-1916. Whites. Tuberculosis absent	64.3	64.8	66.1
295	Inst. Int. de Statistique, ⁸⁹ p. 447	Iceland, 1890-1901	....	64.69	66.89
296	Inst. Int. de Statistique, ⁸⁹ p. 447	Italy, 1910-1912	....	64.67	67.33

TABLE 18—Continued
 E. General and Special Populations (Continued)
 II. Females (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\bar{e}_{15}+15$ (years)	$\bar{e}_{20}+20$ (years)	$\bar{e}_{30}+30$ (years)
297	Glover, ⁷ p. 62	U. S. A. Original Registration States, 1910	63.87	64.66	66.79
298	Inst. Int. de Statistique, ⁸⁹ p. 447	Finland, 1901-1910	.....	64.54	67.30
299	Jones, ⁴² p. 44	Glasgow, 1920-1922	63.76	64.53	66.40
300	Inst. Int. de Statistique, ⁸⁹ p. 446	Bavaria, 1911-1913	.....	64.48	66.44
301	Inst. Int. de Statistique, ⁸⁹ p. 446	Belgium, 1891-1900	.....	64.45	66.95
302	Glover, ⁷ p. 72	U. S. A. Original Registration States, 1901-1910. Whites	63.51	64.39	66.75
303	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1900-1901	.....	64.27	66.42
304	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1901-1910	.....	64.23	66.36
305	Inst. Int. de Statistique, ⁸⁹ p. 448	Ukraine, 1924	.....	64.10	.....
306	Glover, ⁷ p. 218	France, 1898-1903	62.90	64.02	66.93
307	Dublin, ⁴⁹ p. 96	English, Scotch and Welsh born whites, living in New York State, 1910	.....	64.01	.....
308	Inst. Int. de Statistique, ⁸⁹ p. 446	Saxony, 1891-1900	.....	63.96	66.23
309	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1861-1870	.....	63.90	66.20
310	Inst. Int. de Statistique, ⁸⁹ p. 447	Finland, 1911-1920	.....	63.82	66.96
311	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1817-1831	.....	63.80	63.40
312	Glover, ⁷ p. 70	U. S. A. Original Registration States, 1901. Whites	62.79	63.77	66.42
313	Inst. Int. de Statistique, ⁸⁹ p. 446	Prussia, 1891-1900	.....	63.76	65.94
314	Inst. Int. de Statistique, ⁸⁹ p. 446	Belgium, 1881-1890	.....	63.74	66.55
315	Glover, ⁷ p. 218	Italy, 1901-1910	62.43	63.69	66.58
316	Glover, ⁷ p. 218	Switzerland, 1901-1910	62.62	63.69	66.10

317	Inst. Int. de Statistique, ⁹⁹ p. 449	Australia, 1881-1890	63.63	66.13
318	Glover, ⁷ p. 60	U. S. A. Original Registration States, 1901	62.60	66.30
319	Inst. Int. de Statistique, ⁹⁹ p. 447	Iceland, 1850-1860	63.53	66.28
320	Glover, ⁷ p. 110	U. S. A. Original Registration States, 1910. Whites in cities	62.77	65.52
321	Inst. Int. de Statistique, ⁹⁹ p. 447	Holland, 1880-1889	63.50	66.10
322	Glover, ⁷ p. 102	U. S. A. Original Registration States, 1910. Foreign born whites	62.79	65.31
323	Inst. Int. de Statistique, ⁹⁹ p. 447	England and Wales, 1891-1900	63.44	65.39
324	Inst. Int. de Statistique, ⁹⁹ p. 446	Germany, 1891-1900	63.37	65.62
325	Inst. Int. de Statistique, ⁹⁹ p. 446	Bavaria, 1901-1910	63.26	65.48
326	Inst. Int. de Statistique, ⁹⁹ p. 446	Denmark, 1860-1869	63.20	66.10
327	Inst. Int. de Statistique, ⁹⁹ p. 447	Italy, 1899-1902	63.15	66.00
328	Inst. Int. de Statistique, ⁹⁹ p. 446	Wurtemberg, 1891-1900	62.83	65.01
329	Inst. Int. de Statistique, ⁹⁹ p. 448	Sweden, 1856-1860	62.60	65.06
330	Inst. Int. de Statistique, ⁹⁹ p. 448	Sweden, 1841-1845	62.60	64.95
331	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders, 1911-1916. Whites. Tuberculosis present	61.7	62.5
332	Inst. Int. de Statistique, ⁹⁹ p. 447	England and Wales, 1881-1890	62.42	64.76
333	Inst. Int. de Statistique, ⁹⁹ p. 446	Prussia, 1890-1891	62.36	64.67
334	Inst. Int. de Statistique, ⁹⁹ p. 447	Scotland, 1891-1900	62.32	64.90
335	Inst. Int. de Statistique, ⁹⁹ p. 447	France, 1877-1881	62.25	65.50
336	Inst. Int. de Statistique, ⁹⁹ p. 448	Sweden, 1846-1850	62.21	64.48
337	Inst. Int. de Statistique, ⁹⁹ p. 448	Switzerland, 1889-1900	62.20	64.70
338	Inst. Int. de Statistique, ⁹⁹ p. 446	Bavaria, 1891-1900	62.12	64.48
339	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders, 1911-1912. Whites	61.19	62.02
340	Glover, ⁷ p. 100	U. S. A. Original Registration States, 1901. Foreign-born whites	61.11	61.95
341	Inst. Int. de Statistique, ⁹⁹ p. 447	Scotland, 1881-1890	61.93	64.95
342	Inst. Int. de Statistique, ⁹⁹ p. 446	Austria, 1906-1910	61.93	64.80

TABLE 18—Continued
 E. General and Special Populations (Continued)
 II. Females (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\dot{e}_{15}+15$ (years)	$\dot{e}_{20}+20$ (years)	$\dot{e}_{30}+30$ (years)
343	Glover, ⁷ p. 108	U. S. A. Original Registration States, 1901. Whites in cities	60.93	61.86	64.45
344	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1871-1880 .....	....	61.66	64.41
345	Inst. Int. de Statistique, ⁸⁹ p. 446	Germany, 1881-1890 .....	....	61.62	64.21
346	Inst. Int. de Statistique, ⁸⁹ p. 447	France, 1861-1865 .....	....	61.60	65.10
347	Inst. Int. de Statistique, ⁸⁹ p. 446	Denmark, 1835-1844 .....	....	61.60	64.20
348	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1851-1855 .....	....	61.57	63.95
349	Jones, ⁴² p. 29	Glasgow, 1909-1912. Two room house	60.67	61.53	....
350	Inst. Int. de Statistique, ⁸⁹ p. 448	Russian Soc. Fed. Sov. Rep., 1896-1897 ...	....	61.38	64.33
351	Inst. Int. de Statistique, ⁸⁹ p. 446	Austria, 1901-1905 .....	....	61.21	64.22
352	Inst. Int. de Statistique, ⁸⁹ p. 447	Holland, 1870-1879 .....	....	61.20	64.30
353	Inst. Int. de Statistique, ⁸⁹ p. 448	U. R. S. S. European Russia, 1896-1897 ..	....	61.16	64.14
354	Glover, ⁷ p. 218	Japan, 1898-1903	59.36	61.06	64.84
355	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1861-1870 .....	....	61.05	64.26
356	Inst. Int. de Statistique, ⁸⁹ p. 448	Switzerland, 1881-1888 .....	....	60.97	63.76
357	Inst. Int. de Statistique, ⁸⁹ p. 447	Scotland, 1871-1880 .....	....	60.94	64.25
358	Inst. Int. de Statistique, ⁸⁹ p. 446	Austria, 1895-1900 .....	....	60.86	63.84
359	Inst. Int. de Statistique, ⁸⁹ p. 446	Wurtemberg, 1876-1880 .....	....	60.80	63.20
360	Inst. Int. de Statistique, ⁸⁹ p. 448	Sweden, 1816-1840 .....	....	60.75	63.40
361	Inst. Int. de Statistique, ⁸⁹ p. 448	White Russia, 1896-1897 .....	....	60.48	62.94
362	Inst. Int. de Statistique, ⁸⁹ p. 448	Japan, 1921-1925 .....	....	60.38	64.69
363	Inst. Int. de Statistique, ⁸⁹ p. 448	Switzerland, 1876-1880 .....	....	60.30	63.20
364	Inst. Int. de Statistique, ⁸⁹ p. 447	England and Wales, 1838-1854 .....	....	60.29	63.81

365	Inst. Int. de Statistique, ⁸⁰ p. 446	Germany, 1871/72-1880/81	60.19	63.07
366	Inst. Int. de Statistique, ⁸⁰ p. 448	Ukraine, 1885-1898	60.19	....
367	Inst. Int. de Statistique, ⁸⁰ p. 447	Italy, 1876-1887	60.00	63.40
368	Inst. Int. de Statistique, ⁸⁰ p. 446	Prussia, 1867-1877	59.71	62.58
369	Yuan, ⁴⁷ p. 167	Genealogy of a southern Chinese family. All entries	59.7	62.7
370	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders, 1911-1916. Col- ored. Tuberculosis absent	58.3	59.4
371	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders, 1921. Colored ...	57.20	59.03
372	Jones, ⁴² p. 29	Glasgow, 1909-1912. One room house ...	57.85	58.98
373	Inst. Int. de Statistique, ⁸⁰ p. 447	Holland, 1850-1859	58.92	62.16
374	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders, 1930. Colored ..	57.26	58.70
375	Inst. Int. de Statistique, ⁸⁰ p. 446	Austria, 1870-1880	58.28	61.52
376	Yuan, ⁴⁷ p. 168	Genealogy of a southern Chinese family. Births between 1700 and 1749	58.0	61.5
377	Yuan, ⁴⁷ p. 169	Genealogy of a southern Chinese family. Births between 1750 and 1799	57.6	61.1
378	Dublin, ⁴⁸ p. 96	Irish born whites, living in New York State, 1910	57.40	....
379	Yuan, ⁴⁷ p. 168	Genealogy of a southern Chinese family. Births between 1600 and 1699	56.9	61.4
380	Glover, ⁷ p. 82	U. S. A. Original Registration States, 1901. Negroes	54.79	56.89
381	Yuan, ⁴⁷ p. 169	Genealogy of a southern Chinese family. Births between 1800 and 1849	56.8	61.1
382	Inst. Int. de Statistique, ⁸⁰ p. 447	Holland, 1840-1851	56.72	61.03
383	Hernando, ⁴¹ pp. 176 and 177...	Manila, 1920. Native born Filipinos	55.37	56.68
384	Glover, ⁷ p. 84	U. S. A. Original Registration States, 1901- 1910. Negroes	54.05	56.17
			60.09	

TABLE 18—Continued
 E. General and Special Populations (Continued)
 II. Females (Continued)

ITEM NO.	SOURCE	NATURE OF MATERIAL	$\bar{e}_{15}+15$ (years)	$\bar{e}_{20}+20$ (years)	$\bar{e}_{30}+30$ (years)
385	Glover, ⁷ p. 86	U. S. A. Original Registration States, 1910. Negroes	54.18	56.14	59.61
386	Dublin and Whitney, ⁴⁸ p. 442 ..	Industrial policy holders, 1911-1916. Col- ored. Tuberculosis present	53.6	55.7	59.8
387	Jones, ⁴² p. 38	Glasgow, 1870-1872	53.32	55.31	59.35
388	Bull. Met. Life Ins. Co., ⁴⁸ p. 1	Industrial policy holders, 1911-1912. Colored	52.83	55.14	59.32
389	Glover, ⁷ p. 218	India, 1901-1910	45.78	47.96	52.99
390	Unweighted means	Females	61.68	63.74	66.32

⁴⁰ Yuan, I-Chin. The influence of heredity upon the duration of life in man based on a Chinese genealogy from 1365 to 1914. *HUMAN BIOLOGY*, Vol. 4, pp. 41-68, 1932.

⁴¹ Approximate value got by interpolation.

⁴² Office Permanent de l'Institut International de Statistique. Aperçu de la démographie des divers pays du monde. 1931. *La Haye* (Van Stockum) 1932. Pp. xxvi + 469.

⁴³ DePorte, J. V. Life tables for the population of New York State according to nativity. *Amer. Jour. Hyg.*, Vol. 4, pp. 302-326, 1924.

⁴⁴ Hernando, E. Life tables for the native resident population of the city of Manila for the year 1920. *Phil. Jour. Sci.*, Vol. 34, pp. 161-185, 1927.

⁴⁵ Jones, W. The Expectation of Life in the City of Glasgow. *Glasgow* (Robert Anderson) 1925. Pp. vii + 46 + 2 plates.

⁴⁶ Statistical Bulletin Metropolitan Life Insurance Company. Vol. 12, No. 12, December, 1931.

⁴⁷ *Ibid.*, Vol. 9, No. 8, 1928.

⁴⁸ *Ibid.*, Vol. 10, No. 6, 1929.

⁴⁹ Dublin, L. I., E. W. Kopf and A. J. Lotka. The components of death curves. *Amer. Jour. Hyg.*, Vol. 7, pp. 299-333, 1927.

⁵⁰ Yuan, I-Chin. Life tables for a southern Chinese family from 1365 to 1849. *HUMAN BIOLOGY*, Vol. 3, pp. 157-179, 1931.

⁵¹ Dublin, L. I., and Jessamine Whitney. On the costs of tuberculosis. *Quart. Publ. Amer. Stat. Assoc.*, December, 1920, pp. 441-450.

⁵² Dublin, L. I. The mortality of foreign race stocks. *Sci. Monthly*, Jan. 1922, pp. 93-103.

With so much by way of explanation we may proceed to Table 18. In each section of this table the items are arranged in descending order of the values of $\dot{e}_{20} + 20$.

In discussing the data assembled in Table 18 emphasis must first be laid upon the fact that the life table material for parents and grandparents available for citation in sections A, B, C, and D is extremely small, and relates only to American material plus one single Chinese family. It would be foolish to suppose that the means (Items 11, 22, 26, and 30) of the sections mentioned are reliable for purposes of generalization. There is great need for further work along actuarial lines on the problem of the inheritance of life duration, and particularly for the study of material from different racial, social, and economic groups.

Understanding the purely tentative nature of any conclusions, it is of interest to see that the average CML (20) and CML (30)⁶⁰ for *fathers* (Item 11) are respectively 3.69 and 2.32 years *greater* than the corresponding mean figures for males in general (Item 217). Similarly the average CML (20) and the average CML (30) for *mothers* (Item 22) are *greater* than the corresponding means for women in general (Item 390), by 3.52 and 3.01 years respectively. These relations suggest, though they do not prove, that parents may enjoy some excess average longevity over and above that consequent upon their belonging to a selected class experiencing no mortality prior to ages 20 or 30. If this should prove to be the fact on the basis of more extensive experience than we are able at present to assemble, a reasonable biological explanation of it would appear possible, on the ground that parents as a class are presumably sturdier and constitutionally sounder individuals on the average than persons-not-parents, at the same ages during early adult life. There would seem to be, in short, a health factor of some importance involved in the avoidance of parenthood, and of marriage.

The mean CML (20) for fathers (Item 11) is 1.82 years *less* than the mean CML (20) for mothers (Item 22). The corresponding difference, in the same sense, between the mean CML (20)s for males and

⁶⁰ For convenience of discussion in the text we have taken CML (20), meaning "computed average longevity" (total duration of life) of a class of persons all living to age 20 before experiencing any mortality, as a shorthand notation, easily set in type, for $\dot{e}_{20} + 20$. Similarly CML (30) means $\dot{e}_{30} + 30$, and CML (15) means $\dot{e}_{15} + 15$.

females (Items 217 and 390) is 1.99 years. The same comparison of the mean CML (30)s leads to differences of 2.62 years for parents and 1.93 years for persons in general, both differences being again in the same sense. These results indicate, so far as they go, the general actuarial normality of the material upon which sections A and B of Table 18 are based. We do not find here any such discrepancy with well established biostatistical rules as was noted earlier in discussing the biometric data.

The mean CML (20) and CML (30) for grandfathers (Item 26) are greater by 3.46 and 3.86 years respectively than the corresponding means for fathers. Similarly the grandmothers exhibit greater mean values of CML (20) and CML (30) than do the mothers, by amounts of 5.07 and 4.44 years. In short grandparents appear on the face of the case to be definitely longer-lived than parents, and correspondingly even more longer-lived than groups of persons in general living to ages 20 or 30 before experiencing any mortality. The interpretation of this finding is, however, not entirely clear. Why it is not clear will be apparent first from a logical examination of the statistical and biological elements involved in the status of parenthood and grandparenthood, and then from a realization of the dearth, or really almost complete absence, of necessary statistical information about these logically differentiated classes. Let us examine the case from this point of view, listing a series of propositions which appear to be true individually, inclusive as a whole, and individually mutually exclusive. Consider first the kinds of parents who are *parents-not-grandparents* at the time of record. They include:

1. Living parents all of whose children have no offspring at the time of record because they (the children) have not reached the age of puberty.
2. Living parents all of whose children have had no offspring at the time of record because they (the children) have neither married nor engaged in fruitful sexual intercourse.
3. Living parents all of whose children have had no offspring at the time of record because they (the children) are effectively sterile (as evidenced by the fact of completed childless marriage—♀ past the

menopause and/or δ more than 60 years of age, since the number of children engendered by men over 60 is negligibly small).⁶¹

4. Living parents all of whose children have had no offspring at the time of record because they (the children) were divorced before producing any, and have not remarried.

5. Living parents all of whose children have had no offspring at the time of record because they (the children) were widowed before producing any, and have not remarried.

6. Living parents all of whose children have had no offspring at the time of record because they (the children) have previously died childless.

7. Living parents whose children are, as a sibship, some combination of 1-6 inclusive.

8. Dead parents all of whose children have had no offspring at the time of record because they (the children) have not reached the age of puberty.

9. Dead parents all of whose children have had no offspring at the time of record because they (the children) have neither married nor engaged in fruitful sexual intercourse.

10. Dead parents all of whose children have had no offspring at the time of record because they (the children) are sterile (as evidenced by the fact of completed childless marriage— ♀ past the menopause and/or δ more than 60 years of age).

11. Dead parents all of whose children have had no offspring at the time of record because they (the children) were divorced before producing any, and have not remarried.

12. Dead parents all of whose children have had no offspring at the time of record because they (the children) were widowed before producing any, and have not remarried.

13. Dead parents whose children are, as a sibship, some combination of 8-12 inclusive.

We have next to consider the classes of *parents-who-are-not-and-never-can-become-grandparents*. They include:

⁶¹ In the U. S. Registration Area the number of births in any given year sired by all fathers 55 years or over in age is usually less than three-quarters of one per cent of the total births. Unfortunately the Census Bureau does not separately tabulate ages of fathers above 55, but by the time 60 is reached the proportion of children sired must be extremely small, and for all practical statistical purposes entirely negligible.

14. Living parents who never can be grandparents because all of their children never married nor engaged in fruitful sexual intercourse and were, at the time of record, past the physiological age of fertility as defined in 3 *supra*.^{51a}

15. Living parents who never can be grandparents because they are themselves past the physiological age of fertility as defined in 3 *supra*, and all their children were divorced before producing offspring, and did not remarry, if at all, until after they (the children) had passed the physiological age of fertility as defined in 3 *supra*.

16. Living parents who can never be grandparents because they are themselves past the physiological age of fertility, and all their children were widowed before producing offspring, and did not remarry, if at all, until after they (the children) had passed the physiological age of fertility as defined in 3 *supra*.

17. Living parents who never can be grandparents because they are themselves past the physiological age of fertility as defined in 3 *supra*, and their children have all died childless.^{51a}

18. Living parents who never can be grandparents because, as a group, they and their children present together some combination of the specifications included in 14-17 inclusive, and no other.

19. Dead parents who never can become grandparents because all of their children never married nor engaged in fruitful sexual intercourse and were, at the time of record, past the physiological age of fertility as defined in 3 *supra*.^{51a}

20. Dead parents who never can become grandparents because all their children were divorced before producing offspring, and did not remarry, if at all, until after they (the children) had passed the physiological age of fertility as defined in 3 *supra*.

21. Dead parents who never can become grandparents because all their children were widowed before producing offspring, and did not remarry, if at all, until after they (the children) had passed the physiological age of fertility as defined in 3 *supra*.

22. Dead parents who never can become grandparents because all their children died childless.

^{51a} It should be noted that logically Class 14 is a sub-group of Class 2, but for practical statistical reasons it seems advisable to list them as separate classes. The same thing is true of Classes 17 and 6, and Classes 19 and 9.

23. Dead parents who never can become grandparents because, as a group, they and their children present together some combination of the specifications included in 19-22 inclusive, and no other.

It is believed that categories 1-23 inclusive comprise all types of *parents-not-grandparents* capable of being statistically differentiated relative to the variables considered. Of these classes, 3, 10, and 14-23 inclusive are *parents-never-grandparents*, while the remaining classes are *merely-parents-not-grandparents-at-the-time-of-record*. The *parents-never-grandparents* are persons who, while they have been parents, can never achieve the status of grandparenthood under any circumstance, being debarred therefrom by some one or a combination of the stated specifications. The *merely-parents-not-grandparents-at-the-time-of-record* are persons who conceivable still have the *possibility* of achieving grandparenthood at some future time.

It is clearly to be understood that the variables considered in the above array of logical categories are by no means all of those that may be involved in determining the status of persons relative to parenthood and grandparenthood. But they do include those of most importance in dealing with actual statistical data in work on the problems of longevity.

Let us now turn to the consideration of grandparents. Since a grandparent is necessarily always a parent it follows that the classificatory scheme used above needs only to be continued to include the final possible class of parents, namely *parents-also-grandparents*. Of these it is necessary for general statistical purposes to differentiate but six broad classes, *viz.*:

24. Living *parents-also-grandparents*, all of whose children are living at the time of record.

25. Living *parents-also-grandparents*, all of whose children are dead at the time of record.

26. Living *parents-also-grandparents* having both living and dead children at the time of record.

27. Dead *parents-also-grandparents*, all of whose children are living at the time of record.

28. Dead *parents-also-grandparents*, all of whose children are dead at the time of record.

29. Dead *parents-also-grandparents*, having both living and dead children at the time of record.

We have noted above the difficulty of interpretation of the observed greater average CML (20) and CML (30) of grandparents over parents and over cohorts of persons in general in which no mortality had occurred before ages 20 and 30 respectively. The fundamental reason for this difficulty can now be precisely stated. It is that, so far as we are aware, *there does not exist*, for any population, anywhere, exact and comprehensive information as to either (a) *the frequency* in the population, or (b) *the age distribution* of any one of the 29 statistically differentiated types of parents and grandparents listed above. Until such information is available it is impossible to go much below the surface in the analysis of the genetics of longevity. It is our hope to be able in the not too distant future to publish a detailed study that will show, for a fairly large and random population sample, (a) the frequency of occurrence, absolute and relative, (b) the age distribution, and (c) the realized fertility of each of the 29 categories of parents (and grandparents) listed above.

Returning now to Table 18, let us consider briefly some points brought out in Section E, parts I (male) and II (female). Focussing attention upon the CML (20) column, it is seen that the range for males is from 47.46 years mean expected duration of life to 69.40 years. The lowest male figure is for India (1901-1910) and the highest for Denmark (1921-1925). The difference between these two extremes is 21.94 years. Back of this large difference in average longevity lie differences in many other variables, including race, climate, education, hygiene and sanitation, food habits, density of population, etc. Most of these differences can be more or less easily rationalized as the sort of difference that would be expected to lead to the observed difference in average expectation of life at birth. But it is also worthy of note that Denmark has nearly, if not quite, the highest per capita consumption of alcohol of any country in the world, while India has one of the lowest per capita alcohol consumptions.

It is interesting further to note that the countries whose life tables give male CML (20) values of 66 years and above, are (with only one real exception—White Russia) countries populated predominantly with Nordic stocks. On the other hand, the population groups exhibiting CML (20) values below 56 years are either Negroes, Filipinos, Chinese, Irish, or East Indians, or are primarily Nordic stocks existing under

the conditions of public health and sanitation prevailing from a half-century to a century ago.

For the females the range in CML (20) values is from 47.96 years—again for India 1901-1910—to 70.36 years, the computed average longevity of women in New Zealand, 1921-1922. The difference is 22.40 years. In general the racial distribution of the CML (20) values for the females follows closely that for the males, as would naturally be expected.

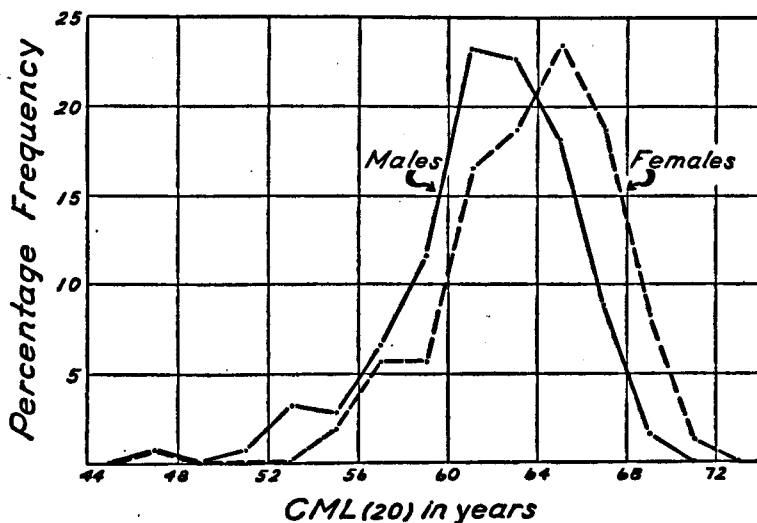


FIG. 16. FREQUENCY POLYGONS SHOWING THE PERCENTAGE DISTRIBUTION OF CML (20)—THAT IS, COMPUTED AVERAGE LONGEVITY OF POPULATIONS EXPERIENCING NO MORTALITY BEFORE AGE 20—VALUES FOR MALES (SOLID LINE) AND FEMALE (DASH LINE), FROM THE LIFE TABLE VALUES OF SECTION E OF TABLE 18

Figure 16 shows the percentage frequency distribution of the CML (20) values in Section E of Table 18.

The diagrams of Figure 16 show clearly the somewhat skew character of the distributions, and the general superiority of the females over the males interracially in longevity.

CHAPTER XII

SIBLINGS OF THE LONGEVOUS



UP TO this point the analysis has been concerned with TIAL and its component elements. It seems desirable, before proceeding to the discussion of the correlations, to present some data regarding the siblings (brothers and sisters) of the propositi in the Long. Series and the FHR Series. To this matter the present chapter is devoted.

Owing to failure of complete recording of the sex of siblings in the original records three cases in the Long. Series and six cases in the FHR Series had to be omitted from the sibling study, leaving for the tables in this section of the investigation 362 sibships in the Long. Series and 137 in the FHR Series. Since the parents of the propositi (and therefore of their sibs) in both series are dead, it is evident that the sibships are complete, and their size represents the completed total realized fertility of the matings from which they came.

Tables 19 and 20 show, for the Long. Series and the FHR Series respectively, the total size of the sibship to which the propositus belonged (*including* the propositus in each case), and the sex-ratio (expressed as percentage of males to total number in the sibship).

It appears that in six cases (1.7 per cent) in the Long. Series, and five (3.6 per cent) in the FHR Series the propositus was an only child. From one the size of the sibship ranges to 16 in the Long. Series data, and to 24 in the FHR Series. The distributions of sibship size are shown graphically in Figure 17.

The biometric constants for size of sibship and sex-ratio are shown in Table 21.

The mean and the median sibships are somewhat larger in the Long. Series than in the FHR Series. The difference between the means cannot be regarded as significant in comparison with its probable error; that between the medians is larger and according to the conventional usage probably is statistically significant. The distributions of Figure 17 indicate clearly that there is a definite tendency of the sibships to run larger in the Long. Series than in the FHR Series. This tendency

TABLE 19
Correlation Table for (a) Male Sex-ratio and (b) Total Size of Sibships of Which the Propositi in the Long. Series Were Members

TOTAL NUMBERS IN SIBSHIP	PERCENTAGE OF ♂♂											ABSOLUTE PERCENT-	
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100	TOTALS	AGES
1	3	..	..	..	..	..	..	..	..	..	3	6	1.7
2	2	..	..	..	..	6	..	..	..	..	4	12	3.3
3	2	..	..	9	..	..	14	..	..	..	4	29	8.0
4	1	..	12	..	..	14	..	10	..	..	3	40	11.0
5	1	..	8	..	12	..	14	..	4	..	3	42	11.6
6 .....	..	2	..	10	..	7	6	..	2	..	1	28	7.7
7 .....	..	2	5	..	13	17	..	9	2	..	..	48	13.3
8 .....	..	1	8	5	..	14	7	5	1	..	..	41	11.3
9 .....	..	1	2	5	9	15	10	3	1	..	..	46	12.7
10 .....	..	..	..	..	4	5	3	1	2	..	..	15	4.1
11	2	..	1	5	2	2	5	4	2	..	..	23	6.4
12 .....	..	..	3	7	1	4	4	1	..	1	..	21	5.8
13 .....	..	..	..	3	..	..	..	1	1	..	..	5	1.4
14 .....	..	..	..	..	..	3	..	..	..	..	..	3	.8
15 .....	..	..	..	..	..	1	..	1	..	..	..	2	.6
16 .....	..	..	..	..	..	1	..	..	..	..	..	1	.3
Totals	11	6	39	44	41	89	63	35	15	1	18	362	100.0

SIBLINGS OF THE LONGEVIOUS

TABLE 20
Correlation Table for (a) Male Sex-ratio and (b) Total Size of Sibships of Which the Propositi in the FHR Series Were Members

TOTAL NUMBERS IN SIBSHIP	PERCENTAGE OF ♂♂											ABSOLUTE TOTALS	PERCENT- AGES
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100		
1	3	..	..	..	..	..	..	..	..	..	2	5	3.6
2	4	..	..	..	..	5	..	..	..	..	1	10	7.3
3	4	..	..	6	..	..	4	..	..	..	1	15	10.9
4	1	..	4	..	..	6	..	3	..	..	1	15	10.9
5	..	..	2	..	6	..	9	..	4	..	..	21	15.3
6	..	..	..	3	..	5	2	..	1	..	..	11	8.0
7	..	..	3	..	2	4	..	5	1	..	..	15	10.9
8	..	..	..	1	1	3	5	1	1	..	..	12	8.8
9	..	..	1	1	1	1	1	1	..	..	..	6	4.4
10	..	..	..	..	2	4	1	3	..	..	..	10	7.3
11	..	..	..	1	..	1	2	..	..	..	..	4	2.9
12	..	..	1	1	1	1	2	1	..	..	..	7	5.1
13	..	..	..	..	..	..	..	..	..	..	..	..	...
14	..	..	..	..	..	1	1	..	..	..	..	2	1.5
15	..	..	..	..	2	..	..	1	..	..	..	3	2.2
24	..	..	..	..	..	1	..	..	..	..	..	1	.7
Totals	12	..	11	13	15	32	27	15	7	..	5	137	99.8

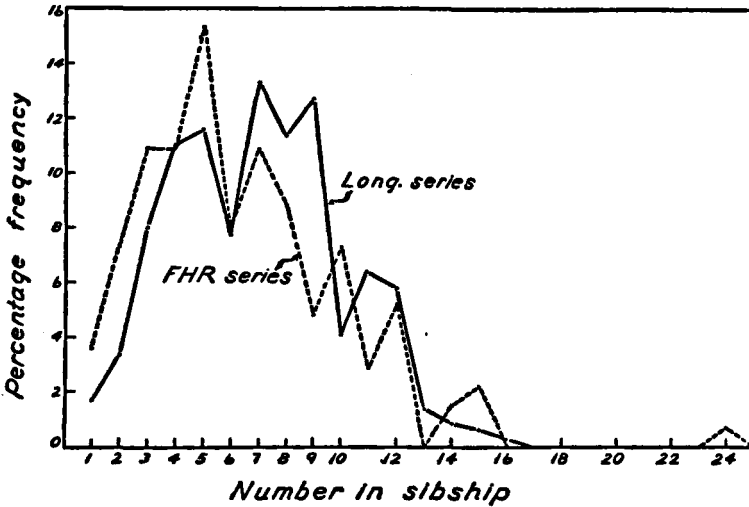


FIG. 17. FREQUENCY POLYGONS FOR SIBSHIP SIZE

towards larger sibship sizes in the Long. Series suggested in Table 21 is consonant with the idea that great longevity, individual or familial, is one mark of high general biological vigor and strength in the stock, which may also express itself in high fertility. The longevous person or family appears to be biologically superior in a variety of respects.

The Long. Series sibships are somewhat less variable in size, both absolutely and relatively, than the FHR Series sibships, but by amounts so small as to be of no great moment biologically, in our view.

TABLE 21

Biometric Constants for Size of Sibship and Sex-ratio

	SIZE OF SIBSHIP		SEX RATIO	
	Long. Series	FHR Series	Long. Series	FHR Series
Mean	7.02 ± .11	6.43 ± .21	53.31 ± .76	52.55 ± 1.31
Median	7.00 ± .14	5.73 ± .26	54.49 ± .95	55.47 ± 1.64
Standard deviation..	3.03 ± .08	3.62 ± .15	21.35 ± .54	22.75 ± .93
Coefficient of variation	43.18 ± 1.27	56.35 ± 2.95	40.05 ± 1.16	43.29 ± 2.08

Again the male sex ratio appears to be about normal and not markedly different in the two series of data, either in magnitude or variability. The slight excess male production and lower variability in the Long Series probably cannot be regarded as significant.

Altogether we conclude that the longevous families and those of the FHR Series are substantially similar in respect of the two biologically important variables fertility and sex ratio, with a somewhat greater fertility in the longevous families.

It is plain from inspection of the tables that there is no marked degree of correlation between the two variables sex-ratio and size of sibship.

The present data give no strong support to the interesting and ingenious theory of Pitt-Rivers⁵² that increasing masculinity is associated with population decline in numbers. An expected corollary of this view would be that in groups showing relatively higher masculine sex-ratios there would be associated relatively lower fertilities, and *vice-versa*, and generally a negative or inverse correlation between male sex-ratio and fertility. The present material is, however, not strictly pertinent to the elucidation of Pitt-Rivers' point, because the fertilities and the sex-ratios of Tables 19 and 20 appertain to the same sibships, while presumably what is needed is the sex-ratios of the *parental* sibships (which are not here tabled) and the fertilities of a group of parents from those sibships (which are here tabled). At the same time it might not be wholly unreasonable to expect a negative correlation in the present material, if the theory were operating, because of the known fact that fertility is in some degree inherited.

We may turn our attention next to the *mortality* that has been experienced in the sibships in the Long Series and the FHR Series. A complete actuarial analysis of these sibships will not be undertaken here, for two reasons. The first is that it is not essential for the purposes of the present study; the second is that we intend later to construct complete life tables for the sibships to which nonagenarians and centenarians belong, using the whole of our material, which is much more extensive than the present Long Series sample limited by the TIAL

⁵² Pitt-Rivers, G. H. L.-F. *The Clash of Culture and the Decline of Races*. London (Routledge) 1927. Pp. xiv + 312. See especially the "Supplement on Sex-ratio," pp. 243-275.

restrictions, as has already been pointed out. It will suffice for present purposes to show the distributions of the living and the dead in the Long. and the FHR Series, as is done in Table 22, and then in Table 23 present the biometric constants for age in the various groups of siblings.

TABLE 22

Absolute and Percentage Distributions by Age (For All Persons of Recorded Age) of the Dead and Living at the Time of Record in the Sibships to Which the Propositi Belong in the Long. Series and the FHR Series

AGE (years)	LONG. SERIES				FHR SERIES			
	No. dead under stated age	Per cent dead	No. still living under stated age	Per cent still living	No. dead under stated age	Per cent dead	No. still living under stated age	Per cent still living
10	252	11.5	0	0	188	20.8	2	.22
20	322	14.8	0	0	226	24.9	16	1.8
30	444	20.3	0	0	285	31.5	57	6.3
40	553	25.3	0	0	329	36.3	179	19.8
50	644	29.5	1	.05	362	40.0	320	35.3
60	744	34.1	4	.18	382	42.2	440	48.6
70	903	41.4	15	.69	389	42.9	498	55.0
80	1225	56.1	55	2.5	389	42.9	516	57.0
90	1571	72.0	131	6.0	389	42.9	517	57.1
100	1666	76.3	458	21.0	389	42.9	517	57.1
110	1667	76.4	516	23.6	389	42.9	517	57.1

From Table 22 the following points are to be noted:

1. In the Long. Series the mortality is absolutely completed at all ages below 40 years, since there remain no persons still living below those ages, and is practically completed at all ages below 80 years, since only 55 persons (or only 2.5 per cent of the total) are still living at ages below 80. The case is quite different in the FHR Series where at no age (considering only 10 year classes) can the mortality be regarded as theoretically complete, since there are still some living persons in each age class up to 90 years.

2. But even though the FHR Series mortality is incomplete at the lower ages, while the Long. Series mortality is complete at the same ages, *the former is much higher than the latter*, at the time of record. Thus up to age 10, in the FHR Series 20.8 per cent of the sibs died, while in the same age period only 11.5 per cent of the Long. Series sibs died.

3. Consider the situation up to age 40. In this period 25.3 per cent of the total number of children ever born in the Long. Series sibships died, leaving 74.7 per cent still surviving at age 40. This compares with a life table percentage of 65.9 surviving at age 40.⁷ In this same life table (Both Sexes, Orig. Reg. States, 1901) the age at which 74.7 per cent of all individuals are still surviving is approximately 25 years, instead of the 40 years of the Long. Series sibships. In other words, *the individuals in sibships to which our nonagenarians and centenarians belonged experienced a much lower mortality below age 40 than do people in general*. Up to 40 years of age the FHR Series sibships had experienced an *incomplete* mortality of 36.3 per cent, and still had 19.8 per cent of all those born living at ages below 40 available for further dying. It seems clear beyond question or doubt that, insofar as mortality is an index, the propositi of the Long. Series belong to stouter stocks, biologically considered, than do those of the FHR Series.

The *infant mortality* record (deaths under one year of age) in the Long. Series sibships is so low as to be worthy of special discussion. In these sibships there were 2183 persons born. Of these there died in the first year of life (i.e., between birth and one year of age) 128, or *5.86 per cent*. In the life table referred to above the deaths in the first year of life amounted to 12.45 per cent. In other words the sibships to which our nonagenarians and centenarians belong experienced an infant mortality *less than half that experienced by the general population roughly some 70 years later* when infant mortality rates generally had been considerably reduced as result of greater knowledge as to infant care, and generally better hygiene and sanitation. As a matter of fact the total mortality in the Long. Series sibships up to age 10 was less than that of the general population during the first year of life in 1901. In the FHR Series sibships the mortality in the first year of life was 14.35 per cent, a figure not widely different from that of the general population in 1901. Nothing could show more clearly the importance of

TABLE 23

Biometric Constants for Age of the Various Groups of Siblings

GROUP	MEAN (years)	MEDIAN (years)	STANDARD DEVIATION (years)	COEFFICIENT OF VARIATION (per cent)
a. Living sibs of propositi. Long. Series.....	81.36± .51	82.70± .64	9.17± .36	11.27± .44
b. Living sibs of propositi. FHR Series.....	44.71± .46	44.27± .57	13.29± .33	29.72± .79
c. All living sibs, including propositi. Long. Series	92.13± .27	93.88± .34	9.06± .19	9.83± .21
d. All living sibs, including propositi. FHR Series	45.77± .41	45.64± .51	13.70± .29	29.93± .68
e. Dead sibs of propositi. Long. Series.....	54.33± .51	65.63± .64	30.65± .36	56.41± .84
f. Dead sibs of propositi. FHR Series.....	17.89± .64	11.71± .80	18.65± .45	104.2± 4.5

sound heredity in respect of longevity as a factor in the reduction of infant mortality than the experience of these Long. Series sibships.

Table 23 gives the biometric constants for age of the various groups of siblings.

Table 23 confirms in another way the conclusions already reached from the figures of Table 22. The Long. Series sibships exhibit an enormously greater store of vitality, as expressed in duration of living up to the time of record, than do the FHR sibships. This remains true after all allowance has been made for the fact that in the nature of the case the FHR sibships are necessarily farther away from the completion of their total living than are those of the Long. Series.

It is of interest to note that while the difference in mean ages (living) of the *propositi* in the two series is 46.68 years (*vide* Table 3 *supra*) the difference in mean age between the living siblings of the *propositi* in the two series is only 36.65 years. In the Long. Series the mean age of the living siblings of the *propositi* is 85.3 per cent of the mean age (living) of the *propositi* themselves. In the FHR Series the corresponding percentage is 91.7. The extremely longevous person tends to be exceptional, even in his own sibship. The mean age of the dead siblings in the Long. Series sibships is 59.0 per cent of the mean age of the living siblings (including the *propositi*) in the same series, while the corresponding percentage for the FHR Series is 39.1. This is another expression of heavy mortality at early ages in the FHR Series as compared with the Long. Series, which has been noted above.

The mean individual total longevity, realized by the dead and expected according to the life table by those still living at the time of record, is for the 2183 members of the Long. Series sibships, 63.88 years, or 14.64 years greater than the expected mean duration of life at birth from the life table for the Original Registration States in 1901 (both sexes). The corresponding figure for the 906 members of the FHR Series sibships is 47.62 years, or 1.62 years less than the life table expectation of life at birth, an insignificant difference.

From Table 10 we have seen that the difference in mean TIAL between the two series is 60.69 years. Hence it may be deduced that, in the two samples here dealt with, an excess in mean TIAL per pedigree of 60.69 years led to an average excess of longevity in the offspring of 16.26 years, or that, on the average, each additional 3.7 years in mean TIAL of the Long. Series over the FHR Series had associated with it one additional year in mean duration of life of the offspring.

CHAPTER XIII

CORRELATIONS



THE correlations in respect of age at death between the various sorts of individuals, or combinations of them, who contribute to TIAL, will necessarily fall into two broad categories, viz.:

a. Homogamic correlations,

measuring the degree of assortative mating between the two sides of the pedigree at various levels. These correlations will throw light upon the question as to how marked the tendencies were in the two series (Long. and FHR) for the immediate ancestors of the propositi to take mates like themselves in respect of duration of life. That is, did persons who in the end achieved relatively great longevity choose in early life mates who also turned out to be relatively highly longevous? And similarly for relatively short-lived persons? It is just such assortative choosing of mates which must take place if high homogamic correlations in respect of longevity are to arise.

b. Kinship (genetic) correlations,

measuring the degree of resemblance between kin in lineal descent, as between father and son for example. It is a cardinal tenet of faith of the Galton-Pearson school of genetic thought that such correlations measure the intensity of inheritance, and do so entirely objectively—uninfluenced logically by any theoretical considerations as to whether mechanism of the hereditary process involved is Mendelian or something else.

With the material available in the present study it is possible to set up under both categories *a* (homogamic) and *b* (kinship) certain correlations that, in the nature of the case, are either:

a. Sensible; that is, make sense biologically.

β. Not sensible; that is, are nonsense correlations biologically.

We propose to exhibit and compare both kinds.

a. Homogamic Correlation

Table 24 shows the sensible assortative mating correlations that can be set up from the available material, dealing with single individuals. In this and all following tables of correlation coefficients the subscripts to r the correlation coefficient refer to the position of the individuals (or combinations of individuals) involved, as set forth in the pedigree shown in Figure 1 *supra*.

TABLE 24
*Theoretically Sensible Simple Homogamic Correlations
in Respect of Longevity*

CORRELATION BETWEEN AGE AT DEATH OF	LONG. SERIES	FHR SERIES
1. Father ⁵³ and mother. ⁵³ r_{of}	+ 0.068 ± .035	+ 0.403 ± .047
2. Father's father ⁵³ and father's mother. r_{ob} ..	+ .239 ± .033	+ .126 ± .056
3. Mother's father and mother's mother. r_{od} ..	+ .069 ± .035	+ .100 ± .056
Means	+ .125	+ .210

We know of no biological reason why all six coefficients of correlation in Table 24 should not be substantially equal to each other. That is to say, if homogamy relative to longevity is a real factor in the selection (conscious or unconscious) of mates for marrying amongst human beings, as has been asserted, then there would seem to be no reason to suppose that its intensity would not be reasonably constant in fairly homogeneous groups of people over so short a time span as a single generation. But actually there is a considerable diversity amongst these six coefficients. Four of the six are not significantly different from

⁵³ Throughout the discussion of correlation, that is in Tables 24-30 inclusive, the designations of persons correlated are *by their kinship to the propositus*. That is to say, in these tables "father" means "father of the propositus," and so similarly for all other cases *mutatis mutandis*. Furthermore if the reader will refer back to Figure 1, and pay attention to the subscripts of r in the correlation discussion, it will be clear at all times what individuals are being correlated.

zero. The other two are quite large, as homogamic correlations go. The mean value for the whole six is 0.168, and the standard deviation 0.120, leading to a coefficient of variation of 71.4 per cent indicative of a rather highly variable state of affairs. Attention should be called to the fact that the high coefficient of +0.403 for the parents in the FHR Series may owe a part of its magnitude to the manner in which the FHR Series was selected, as described in an earlier section of this study. The rule of formation of the group included *inter alia* the requirement that both parents should be dead, and the propositus living. This might have some tendency to make the two parents alike in age at death.

But before discussing further the correlations of Table 24 let us examine the nonsense correlations of Table 25.

TABLE 25

*Theoretically Nonsense Simple Homogamic Correlations
in Respect of Longevity*

CORRELATION BETWEEN AGE AT DEATH OF	LONG. SERIES	FHR SERIES
Father's father with mother's mother. r_{ad}	+ 0.078 ± .035	+ 0.126 ± .056
Mother's father with father's mother. r_{ob}	+ .127 ± .035	+ .039 ± .056
Means	+ .103	+ .083

Taking a broad view of the matter it seems open to some question as to whether the coefficients of Table 25 are widely enough different in their values from those of Table 24 as to indicate any real and significant assortative mating in respect of longevity in this material. The fluctuation of random sampling would seem to have been a considerable factor in the production of the values in the two tables. Of course there may be some prepared to allege that the correlations of Table 25 are not nonsense correlations; that persons do in fact choose their mates upon the basis that his father's longevity, and his intended wife's mother's longevity are similar, and *vice versa*. Perhaps such an allegation is not nonsense, but it seems so to us.

Let us examine next what may be called a compound homogamic correlation, and another compound correlation that may be compared with it. These values are shown in Table 26.

TABLE 26

Compound Homogamic Correlation in Respect of Longevity

VARIABLES CORRELATED	LONG. SERIES	FHR SERIES
(Summed longevity of all three immediate male ancestors) and (Summed longevity of all three immediate female ancestors)		
$r_{(a+c+e) (d+b+f)}$	+0.190±.034	+0.315±.051
(Summed longevity of all three immediate ancestors of propositus on father's side) and (Summed longevity of all three immediate ancestors of propositus on mother's side)		
$r_{(a+b+e) (c+d+f)}$	+0.107±.035	+0.143±.055

While the correlations of Table 26 are by no means very high, still this table makes a different impression than does either Table 24 or Table 25. The coefficients range from 2.6 (in the worst case) to 6.2 (in the best case) times the probable errors. The correlations of the first line of the table (all male with all female ancestors) are respectively 5.6 and 6.2 times their probable errors. So that it would seem that in both the Long. and the FHR Series there is a statistically significant correlation between the three immediate male ancestors of the propositus and the three immediate female ancestors, in regard to their respective summed longevities. This correlation appears to be biologically sensible. It is a little difficult to say whether the correlations of the second line of Table 26 are to be regarded as making sense or nonsense. It depends on the viewpoint. These two correlations, $r_{(a+b+e) (c+d+f)}$, measure the degree of likeness of the two sides of the pedigree in respect of summed longevity. This surely is an interesting and sensible thing to measure, considered in and of itself. But on the

other hand, it is not wholly or strictly an assortative mating or homogamic correlation, and insofar as it is not it is a nonsense correlation relative to homogamy. The actual values of the coefficients are on the borderline of statistical significance (3.1 and 2.6 times their probable errors) and cannot be asserted to be certainly outside the range of chance fluctuation.

A point that ought not to be left without comment is that in Tables 24 and 26 there is an evident tendency for the coefficients to be larger in the FHR Series than in the Long. Series. In the 5 pairs of comparable coefficients the one for the FHR Series is the larger in all but one case. The differences are, to be sure, mostly insignificant statistically in their magnitudes. But the trend seems to be remarkable in that it is opposite to what might be expected *a priori*. If ancestral assortative mating in respect of longevity plays any part in the production of great duration of life, either absolute or relative, in the propositus, then it might reasonably be expected that the homogamic correlations would tend to be higher in the Long. Series than in the FHR Series. But the trend of the actual figures is rather the opposite. As has already been pointed out some part of this result may be due to the manner of formation of the FHR Series. But this consideration would not be likely to affect sensibly the grandparental homogamic correlations.

Many years ago Romanes stressed the fact that homogamy is, in the very nature of the case, an important factor in organic evolution. In fact it is difficult to see why its significance is not potentially as great as that of natural selection, and so far as concerns civilized man perhaps even greater. But it is only in comparatively recent years that any attempt has been made seriously and systematically to measure the extent and degree of assortative mating.

We shall not attempt to review the literature on homogamy in man in any systematic way here, partly because of lack of space and partly because much of it is irrelevant to the present purpose. It may, however, be noted in passing, as evidence we hope of increasing interest in the subject, that Jones,⁶⁴ who has reviewed the subject, finds that when the most reliable intelligence tests are used the homogamic correlation for intellectual abilities tends to take values of about $+0.5$. Willough-

⁶⁴ Jones, H. E. Homogamy in intellectual abilities. *Amer. Jour. Soc.*, Vol. 35, pp. 369-382, 1929.

by,⁵⁵ an active worker in this field, has studied five modern population groups and two historical populations relative to the degree of homogamy in respect of fertility. He finds that in his modern population groups the fertility homogamic correlations range from -0.13 to values of the order of $+0.30$, with a tendency for higher degrees of homogamy in the economically superior groups. Crux and Haeger⁵⁶ reach the unexpected, and so far as we are aware unconfirmed conclusion that normally mate choice in man follows the rule of opposites in respect of bodily habitus, the pyknic tending to choose the asthenic, and *vice versa*. They allege that deviations from this rule usually indicate personalities injured by unfortunate childhood experiences. It is difficult to reconcile this conclusion with the results of Pearson and Lee,⁵⁷ Rosinski,⁵⁸ and Willoughby⁵⁹ who find significant positive correlations between husband and wife in respect of a number of physical characters of the body, each taken singly. Thus we have the following values:

Character	Pearson and Lee	Rosinski	Willoughby
Stature	$+0.280 \pm .019$	$+0.138$	$+0.16$
Span	$+ .199 \pm .020$	.....	.....
Forearm length	$+ .198 \pm .021$	.....	.....
Face width .....	.....	.....	$+ .15$
Form of lips.....	.....	$+ .475$	.....
Head width .....	.....	.....	$+ .10$
Head length .....	.....	.....	$+ .06$
Form of nose.....	.....	$- .177$	.....
Facial index .....	.....	$+ .076$	.....
Face width index.....	.....	.....	$+ .08$
Nasal index .....	.....	$- .066$	.....
Cephalic index .....	.....	$+ .006$	$+ .08$

⁵⁵ Willoughby, R. R. Homogamy in fertility. *Eug. Rev.*, Vol. 23, pp. 223-229, 1931.

⁵⁶ Crux, J. and F. Haeger. Körperbau und Gattenwahl. *Ztschr. f. Sex.-wiss. u. Sex.-pol.*, Bd. 17, pp. 337-348, 1930.

⁵⁷ Pearson, K. and Alice Lee. On the laws of inheritance in man. I. Inheritance of physical characters. *Biometrika*, Vol. 2, pp. 357-462, 1903.

⁵⁸ Rosinski, B. Anthropogenetische Auslese. *Anthrop. Anz.*, pp. 49-64, 1929.

⁵⁹ Willoughby, R. R. Somatic homogamy in man. *Human Biology*, Vol. 5, pp. 690-705, 1933.

The pioneer investigation regarding homogamy in respect of duration of life, and still the most extensive one, is the study made over 30 years ago by Pearson⁶⁶ and his co-workers on English tombstone and genealogical records. The homogamic correlations obtained were remarkably consistent, and ran as follows:

Correlation Between Husband and Wife in Age at Death (Pearson)

Wensleydale and District (Tombstones)	+0.2200 ± .0244
Oxfordshire (Tombstones)	+ .2500 ± .0211
London (Tombstones)	+ .4204 ± .0176
Society of Friends (Genealogies)	+ .1999 ± .0212

The London value is thought to be too high and is excluded in forming the average figure of +0.2233. Our mean value of +0.210 for the FHR Series (Table 24) is in rather close agreement with this. But even so we are still somewhat reluctant, in view of the very considerable variation shown by our coefficients and their disturbing nearness to comparable nonsense correlations, to accept as demonstrated the reality of a sensible and significant assortative mating in man in respect of longevity. It would seem prudent to wait for more extensive and confirmatory evidence before accepting such a conclusion unreservedly. Stoessiger's⁶⁸ recent study of Pearson's family data gives a lower value (+0.1564 ± .0197) than those cited above from the earlier work.

b. Kinship (Genetic) Correlations

In Table 27 are presented all of the possible theoretically sensible simple kinship correlations that can be derived from the present material.

In but one of the eight parent-offspring correlations exhibited in Table 27 is the coefficient three or more times its probable error. But before discussing further the data of this table we wish to present the corresponding nonsense correlations—nonsensical because it cannot be reasonably alleged that a man or woman inherits anything biologically from his or her *consort's* parents.

⁶⁶ Assortative mating in man. A coöperative study. *Biometrika*, Vol. 2, pp. 481-498, 1903.

TABLE 27

*Theoretically Sensible Parent-Offspring Correlations in
Respect of Longevity*

CORRELATION IN RESPECT OF AGE AT DEATH BETWEEN	LONG. SERIES	NO. OF PAIRS
Father's father and father (Father and son type) r_{af}	+0.093±.035	365
Father's mother and father (Mother and son type) r_{bf}	+ .157±.034	365
Mother's father and mother (Father and daughter type) r_{mf}	+ .016±.035	365
Mother's mother and mother (Mother and daughter type) r_{mf}	+ .067±.035	365
Mean numerical values (regardless of signs)	.083	
	FHR SERIES	NO. OF PAIRS
Father's father and father (Father and son type) r_{af}	+0.086±.056	143
Father's mother and father (Mother and son type) r_{bf}	— .006±.056	143
Mother's father and mother (Father and daughter type) r_{mf}	+ .159±.055	143
Mother's mother and mother (Mother and daughter type) r_{mf}	+ .003±.056	143
Mean numerical values (regardless of signs)	.064	

Having regard to the probable errors involved there is plainly little to choose between sensible Table 27 and nonsensical Table 28, so far as the intensity of correlation, as measured by the coefficients, is concerned. In point of fact the four nonsense coefficients have actually a higher average numerical value than the four sensible coefficients, in the case of the FHR Series.

Furthermore if Table 27 be compared with Table 24 it is seen that the mean sensible homogamic correlations are actually higher (though

TABLE 28

*Theoretically Nonsense Parent-offspring Correlations in
Respect of Longevity*

CORRELATION IN RESPECT OF AGE AT DEATH BETWEEN	LONG. SERIES	NO. OF PAIRS
Father's father and subject's mother, r_{af}	-0.022±.035	365
Father's mother and subject's mother, r_{bf}	- .061±.035	365
Mother's father and subject's father, r_{of}	+ .033±.035	365
Mother's mother and subject's father, r_{df}	+ .032±.035	365
Mean numerical values (regardless of signs)	.037	
	FHR SERIES	NO. OF PAIRS
Father's father and subject's mother, r_{af}	+0.045±.056	143
Father's mother and subject's mother, r_{bf}	- .147±.055	143
Mother's father and subject's father, r_{of}	+ .050±.056	143
Mother's mother and subject's father, r_{df}	+ .070±.056	143
Mean numerical values (regardless of signs)	.078	

not significantly so) than the mean sensible parent-offspring correlations in both series. This surely is an odd state of affairs, in view of the fact, which we believe has been abundantly demonstrated by the evidence presented in this study, that heredity plays an important part in the biological determination of longevity.

Tables 29 and 30 present respectively sensible and nonsense compound kinship (parent-offspring) correlations, which are in fact equivalent to correlations between an individual and his mid-parent, in the Galtonian sense of the word.⁶⁰

⁶⁰ Galton took as mid-parental values for correlational purposes the mean of the two parental values of the variable concerned, making where necessary a sex-correction to bring female measures into equivalence with male. It can make no essential difference in the results so far as concerns *correlation* if one takes (father + mother)/2, or simply (father + mother) as we have done here.

It is apparent that the compound or mid-parent-offspring correlations are not substantially different from the simple parent-offspring correlations of Table 27. There is the same considerable variation, and the same lack of convincing evidence of any general or real departure from zero correlation.

TABLE 29

Theoretically Sensible Mid-parental-offspring Correlations in Respect of Longevity

CORRELATION IN RESPECT OF AGE AT DEATH BETWEEN	LONG. SERIES	NO. OF PAIRS
(Father's father + father's mother) and father. $r_{(a+b)e}$	+0.159±.034	365
(Mother's father + mother's mother) and mother. $r_{(c+d)f}$	+ .071±.035	365
Means	+ .115	
	FHR SERIES	NO. OF PAIRS
(Father's father + father's mother) and father. $r_{(a+b)e}$	+0.058±.056	143
(Mother's father + mother's mother) and mother. $r_{(c+d)f}$	+ .105±.056	143
Means	+ .082	

The nonsense correlations of Table 30 are somewhat smaller on the whole, than the sensible correlations of Table 29, but not by amounts likely to convince anyone that the latter are really any different from the former.

Finally two other compound kinship correlations may be presented. They are of the type $r_{(a+b+c+d)(e+f)}$, that is the correlation between the summed ages at death of all the grandparents and the summed ages at death of both parents. The values of this coefficient are: for the Long. Series + 0.087 ± .035, and for the FHR Series + 0.060 ± .056. Neither significantly departs from zero correlation.

Summing up the whole case regarding parent-offspring correlations derived from the present data, we are led to essentially the same con-

TABLE 30

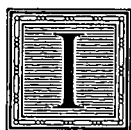
Theoretically Nonsense Mid-parental-offspring Correlations in Respect of Longevity

CORRELATION IN RESPECT OF AGE AT DEATH BETWEEN	LONG. SERIES	NO. OF PAIRS
(Mother's father + mother's mother) ⁵⁸ and father. $r_{(a+d)e}$	+0.037±.035	365
(Father's father + father's mother) and mother. $r_{(a+b)f}$	— .047±.035	365
	FHR SERIES	NO. OF PAIRS
(Mother's father + mother's mother) ⁵⁸ and father. $r_{(a+d)e}$	+0.061±.056	143
(Father's father + father's mother) and mother. $r_{(a+b)f}$	— .126±.056	143

clusion as was reached by one of us* in an earlier study. The gist of this conclusion is that, for reasons unknown to us, the method of kinship correlation, regardless of the material to which it has so far been applied, leads to values of the correlation coefficients so low absolutely, and so variable amongst themselves both as to sign and as to magnitude, as to be out of accord with the now considerable and convincing body of other kinds of evidence, as well as elementary common observation, showing that heredity plays a really important rôle in the determination of individual longevity in man. It is our opinion that the biometric method of correlation, as it has hitherto been applied to the problem of the inheritance of longevity, is an inadequate and unreliable method so far as concerns this problem. Nothing in either the papers of Beeton and Pearson,^{20,27,28} nor in the most recent work from the same laboratory²⁹ appears to furnish any ground for altering the opinion. We propose to continue our search to find out the reason for the discrepancy between the results given by the method of correlation and other methods, including the actuarial, in regard to the problem of inheritance of longevity. But at the same time we intend to get all the light we can on the problem by the use of other methods, which so far have yielded results which seem to us to be more trustworthy.

CHAPTER XIV

MATINGS THAT PRODUCED THE LONGEVOUS



IN COMMON parlance, and upon the basis of the life table, the life duration of ancestors (that is of persons who survive to roughly at least 20 years of age) can fairly be thrown into three broad categories quantitatively, as follows:

- A. Under 50 years.
- B. From 50 to 69 years inclusive.
- C. 70 years and over.

For convenience we shall designate persons falling in Class A as "Short-lived" in respect of age at death; those falling in Class B as "Average"; and those in class C as "Long-lived." Table 31 shows, in the two columns of figures on the left side the absolute and percentage frequencies of all the matings of parents which produced the propositi in the Long. Series—that is our 365 nonagenarians and centenarians—the matings being classified according to the above broad categories of age. The two right hand columns of figures give the same data for the

TABLE 31

*Matings Producing the Propositi in the
Long. and FHR Series*

NATURE OF <i>Father</i>	MATING <i>Mother</i>	LONG. SERIES MATINGS		FHR SERIES MATINGS	
		<i>Absolute frequency</i>	<i>Percentage frequency</i>	<i>Percentage frequency</i>	<i>Absolute frequency</i>
Short-lived	× Short-lived	10	2.7	19.6	28
Short-lived	× Average	8	4.9	18.2	3
Average	× Short-lived	10			
Short-lived	× Long-lived	31	17.5	9.8	5
Long-lived	× Short-lived	33			
Average	× Average	21	5.8	19.6	28
Average	× Long-lived	51	23.3	21.0	15
Long-lived	× Average	34			
Long-lived	× Long-lived	167	45.8	11.9	17
Totals		365	100.0	100.1	143

matings producing the propositi of the FHR Series. The table is so arranged as to bring the percentage frequencies for the two series contiguous to each other.

Table 31 shows clearly the striking difference in the character of the matings relative to longevity which produced the nonagenarians and centenarians on the one hand and the FHR propositi on the other hand. In the Long. Series there were proportionally nearly four times as many matings of the type Long-lived \times Long-lived as in the FHR Series. Conversely there were over seven times as many matings of the type Short-lived \times Short-lived involved in the production of the propositi in the FHR Series as in the production of the propositi in the Long. Series. Furthermore in the Long. Series there were but 5.8 per cent of the matings of the type Average \times Average, as against 19.6 per cent of this type of mating in the FHR Series.

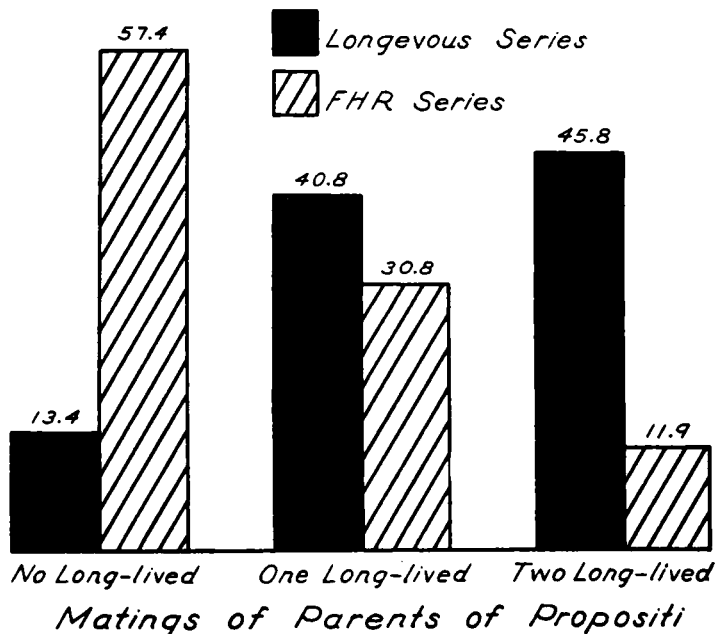


FIG. 18. BAR DIAGRAM SHOWING THE PERCENTAGES OF MATINGS OF PARENTS PRODUCING THE PROPOSITI WHICH INVOLVED (A) NO LONG-LIVED PARENT, (B) ONE LONG-LIVED PARENT, (C) TWO LONG-LIVED PARENTS IN THE LONGEVIOUS SERIES (SOLID BARS) AND THE FHR SERIES (CROSS-HATCHED BARS)

Figure 18 shows in graphic form the result of assembling the matings of Table 31 into three categories, according to whether they involved (a) no long-lived person, (b) one long-lived person, (c) two long-lived persons.

It is evident that in the matings which produced the nonagenarians and centenarians the percentage of long-lived parentage *increases* as we pass from left to right in Figure 18, while conversely in the matings which produced the propositi in the FHR Series the percentage of long-lived parentage steadily *decreases* from left to right. Nearly 87 per cent of the parental matings producing nonagenarians and centenarians involved one or more long-lived persons, while in the FHR Series there were only about 43 per cent of such matings.

Let us next examine in the same way the matings in each series which produced the *parents* of the propositi. There will be two tables corresponding to Table 31, one for the matings producing the *fathers* of the propositi and one for those producing the *mothers*. Relative to the propositi these are *grandparental* matings that we shall now study. Table 32 gives the data for the matings producing the *fathers* of the propositi.

Table 32 exhibits a number of points of interest in comparison with Table 31. In the first place the percentage columns for the two series

TABLE 32
Matings Producing the Fathers of the Propositi in the Long. and FHR Series

NATURE OF MATING		LONG. SERIES MATINGS		FHR SERIES MATINGS	
<i>Father's father</i>	<i>Father's mother</i>	<i>Absolute frequency</i>	<i>Percentage frequency</i>	<i>Percentage frequency</i>	<i>Absolute frequency</i>
Short-lived × Short-lived		5	1.4	0.7	1
Short-lived × Average		5}	3.6	16.8	{11
Average × Short-lived		8}			
Short-lived × Long-lived		15}	7.7	11.9	{9
Long-lived × Short-lived		13}			
Average × Average		20	5.5	6.3	9
Average × Long-lived		53}	25.2	27.3	{26
Long-lived × Average		39}			
Long-lived × Long-lived		207	56.7	37.1	53
Totals		365	100.1	100.1	143

while still significantly different from each other are in some respects less different than in Table 31. That is to say, these grandparental matings are somewhat more nearly alike, for the two series, in respect of the longevities involved, than are the parental matings. This result is in accord with the earlier findings (Table 16, and Figures 13-15 *supra*) that the grandparents in the two series tended to be less differentiated from each other and from the general population than parents.

In both the Long. and FHR Series the percentages of matings of the Long-lived \times Long-lived type are higher in Table 32 than in Table 31, by substantial amounts; at the same time the Short-lived \times Short-lived matings are proportionately fewer in Table 32, particularly in the FHR Series, where there is only one (0.7 per cent) such grandparental mating.

Table 33 gives the data regarding the matings which produced the *mothers* of the *propositi*.

TABLE 33
Matings Producing the Mothers of the Propositi in the Long. and FHR Series

NATURE OF MATING		LONG. SERIES MATINGS		FHR SERIES MATINGS	
<i>Mother's father</i>	<i>Mother's mother</i>	<i>Absolute frequency</i>	<i>Percentage frequency</i>	<i>Percentage frequency</i>	<i>Absolute frequency</i>
Short-lived \times Short-lived		3	0.8	3.5	5
Short-lived \times Average		7	3.0	13.3	6
Average \times Short-lived		4			13
Short-lived \times Long-lived		21	12.1	18.2	15
Long-lived \times Short-lived		23			11
Average \times Average		16	4.4	9.8	14
Average \times Long-lived		51	26.3	25.2	18
Long-lived \times Average		45			18
Long-lived \times Long-lived		195	53.4	30.1	43
Totals		365	100.0	100.1	143

Table 33 is plainly rather closely similar to Table 32. The breeding of the mothers of the *propositi*, in other words, is of about the same sort as that of the fathers so far as concerns longevity.

The significant differences between the breeding of the *propositi*, on the one hand, and their parents on the other hand, are clearly set forth for both Long. and FHR Series in Table 34, which summarizes Tables 31-33 inclusive.

TABLE 34
Summary of Tables 31-33 Inclusive

MATINGS PRODUCING	LONGEVIOUS SERIES			FHR SERIES		
	<i>Percentage of matings with</i>			<i>Percentage of matings with</i>		
	<i>No long-lived parent</i>	<i>Only one long-lived parent</i>	<i>Two long-lived parents</i>	<i>No long-lived parent</i>	<i>Only one long-lived parent</i>	<i>Two long-lived parents</i>
Fathers of propositi	10.5	32.9	56.7	23.8	39.2	37.1
Propositi	18.4	40.8	45.8	57.4	80.8	11.9
Mothers of propositi	8.2	38.4	53.4	26.6	43.4	30.1

From the data presented we see:

1. That for two generations back of the propositi in the Long. Series (nonagenarians and centenarians) roughly something like one-half of all the individual matings have been composed of two Long-lived persons, the proportions being approximately 46 to 57 per cent of all matings concerned. In the breeding of the propositi of the FHR Series, on the other hand, there have been for two generations back only from about 12 to 37 per cent of all the matings concerned which have been composed of two Long-lived persons.

2. That only about a tenth (8.2 to 13.4 per cent) of all the individual matings for two generations back in the production of the nonagenarians and centenarians have involved no Long-lived persons. But in the FHR Series from 23.8 to 57.4 per cent of all the individual matings for two generations back of the propositi have included no Long-lived person.

3. The proportions of all individual matings involving only one Long-lived parent are in general roughly of the same order of magnitude in both the Long. and the FHR Series. But there are curious and orderly differences in detail. In the parental matings to produce the propositi the percentage of only-one-parent-long-lived matings is *higher* in the Long. Series (40.8 per cent) than in the FHR Series (30.8 per cent). But the opposite is true in the grandparental matings to produce the parents of the propositi, where the FHR Series has, in both cases, higher percentages of one-parent-long-lived matings than does the Long. Series.

CHAPTER XV

SUMMARY AND CONCLUSIONS



IN THIS study we have analyzed and compared the ancestry in respect of their longevity of two groups of persons. One of these groups (called the Longevous or Long. Series) consists wholly of persons still living at ages of 90 years and above—83.8 per cent nonagenarians and 16.2 per cent centenarians in fact. The other group (called the FHR Series) consists of the oldest living siblings (except in a few cases where there were no living sibs and the oldest dead ones were taken) from sibships taken at random so far as concerns longevity. Both groups are alike in the fact that the six immediate ancestors (two parents and four grandparents) were dead and of known and recorded ages at death. In the present analysis no attempt has been made to differentiate between different causes of death of the ancestors, and in particular there has been no effort to separate so-called “accidental” deaths from those generally regarded as non-accidental. Doubtless this will be regarded by some as a serious defect of the study. But whether it is so regarded or not will depend somewhat upon the point of view and upon an adequate apprehension of both the problem and the inherent difficulties in the case.⁶¹ In this first

⁶¹ We have studied and thought about the causes of death for a good many years, and find it increasingly difficult to discover or define any sharp discontinuity between accidental and non-accidental causes. Consider, for example, Figure 9 *supra*. Is death from smallpox an accident or not? Is death in childbirth an accident? Because in this pedigree deaths from these causes occurred at young ages the tendency is to think of them as accidental, in the sense that they may have cut off the individuals concerned before they had had a chance to realize their innate biological potentialities of longevity. But does not the fact that some persons survive childbirth and some survive attacks of smallpox indicate that the constitution of the individual plays at least some part in the death or survival of those subjected to these particular biological stresses? Again consider pneumonia as a cause of death. A distinguished medical friend and correspondent always insists in discussions of this matter that all pneumonia deaths should be regarded as just as truly accidents as is being killed by an automobile. But on the other hand we

study of the material our judgment has been to present the data as they stand. If, as is the fact, they indicate when so presented *in toto* a definite and considerable influence of heredity in the determination of individual longevity the result is strengthened rather than weakened by the fact that accidental deaths among the ancestors are included.

What then are the more important and essential⁶² results of this analysis? To us they seem to be those listed below. For the more detailed results the body of the text must be consulted.

have presented a considerable body of evidence⁶³ indicating that the biological constitution of the individual plays a not unimportant rôle in determining whether he acquires and/or dies of pneumonia. Examples of the inherent difficulty, not to say impossibility of sharply defining and differentiating accidental deaths could be multiplied endlessly. Consider the case of the man who takes a trip and becomes infested with *Endamoeba histolytica* and subsequently dies from eating food prepared by a hotel cook who is a carrier. Such a death may from one point of view be regarded as accidental. But shall we, because such cases occur, regard intestinal amoebiasis generally as an accidental cause of death? Surely the weight of opinion would be against such an allocation. And so on through the whole list of infectious diseases. The same argument could be advanced for all of them. Furthermore it has been cogently argued by many that even deaths from being hit by an automobile are in some degree biologically selective. The argument is that it is the less alert, the less biologically fit, that are eliminated in this way. Obviously it is possible to push this type of argument too far, but it is difficult to deny that it contains some element of truth.

We have come to the conclusion that for the present at least it will be best to keep the study of the inheritance of human longevity on as completely an objective basis as possible, ruthlessly taking all accurately recorded ages at death at their face value, without any attempt to explain away by an appeal to accident any of them that may for theoretical reasons be uncomfortable. This position can furthermore be maintained with perhaps enhanced equanimity because it has been shown (cf. for example Stoessiger⁶⁴) that when the so-called "accidental" deaths are alternatively included and excluded in the statistical analysis relating to inheritance of longevity there results no significant difference in any important conclusions.

⁶² We are fully aware of the fact that the present study does not analyze or discuss all the aspects of the material used. It is to be regarded solely as one stage or step in the development of our program of research on longevity. We expect to return later to the discussion of various problems upon which the present material is capable of shedding light, but which are omitted here from considerations of space.

1. The range of variation in TIAL (total immediate ancestral longevity, the summed ages at death of the six immediate ancestors of the propositi) is from 254 to 599 years. Both of these extreme figures occur in the Long. Series. In other words the whole range of variation in the TIALs of the FHR Series is included within that of the Long. Series (Table 9).

2. The mean and median TIALs of the nonagenarians and centenarians are over 60 years or nearly 16 per cent *greater* than those of the FHR Series, indicating statistically the importance of ancestral longevity in determining that of the individual (Table 10), even after all due allowance is made for the statistical consequences of the manner of selection of the FHR Series analyzed in Chapters IV and IX.

3. Not only is the mean TIAL greater in the Long. than in the FHR Series, but also the average age at death of every single ancestor (fathers, mothers, paternal and maternal grandfathers and grandmothers) of the group of nonagenarians and centenarians is greater than that of the corresponding ancestor of the FHR group (Table 15). The magnitudes of these average ancestral superiorities in longevity are of the order of 20 to 30 per cent in the case of the parents, and 10 to 14 per cent in the case of the grandparents (Figure 13). They are from 6 to 15 times their probable errors (Table 16) and therefore cannot be regarded as mere fluctuations of sampling.

4. It follows from paragraph 3 that since all of the individual ancestors taken separately are on the average definitely more longevous in the Long. than in the FHR group, any combination of them (as for example all male ancestors, all ancestors on the father's side, etc.) should show differences in the same sense. They do in fact (Tables 11, 13, 14).

5. The average longevity of the ancestors of the group of nonagenarians and centenarians appears to be generally greater than that of corresponding ancestors of persons not similarly selected for their own longevity (Table 17), and generally greater than that of comparable persons belonging to various general and special populations (Table 18).

6. But even though the statistical superiority of the ancestors of the group of nonagenarians and centenarians is clear and considerable, as has been pointed out in the preceding paragraphs, it is also an important fact that 13.4 per cent of the nonagenarian and centenarian group were bred from matings in which *neither* parent was Long-lived ("Long-lived" being defined as living 70 or more years). That is to say, that

while 86.6 per cent of our group of highly longevous persons had either one or both parents Long-lived, there was a residue of about 1/7 of them who had no Long-lived parents. The same was true of 10.5 per cent of their fathers and 8.2 per cent of their mothers (Table 34). So it appears that extremely longevous persons *may* be bred from Short-lived or Average ancestry, in a small but not negligible proportion of all cases.

7. On the other hand 45.8 per cent of the nonagenarians and centenarians, 56.7 per cent of their fathers, and 53.4 per cent of their mothers had *both* of their parents in the Long-lived category (Table 34). These figures contrast with 11.9, 37.1 and 30.1 per cent for the FHR Series. Furthermore it must be noted that in the FHR Series 57.4 per cent of the propositi, 23.8 per cent of their fathers, and 26.6 per cent of their mothers had *neither* parent Long-lived. Altogether it appears that not only is the highly longevous group statistically superior in *average* ancestral longevity, but also they are bred from individual matings of marked superiority in respect of longevity.

8. The sibships to which the nonagenarians and centenarians belong are somewhat larger on the average than those to which the propositi in the FHR Series belong, and had experienced a definitely lower mortality up to the time of record than either the FHR sibships or the general population. The infant mortality (deaths under one year of age) in Long. Series sibships was only 5.86 per cent, as against 12.45 per cent in the life table population of 1901, and 14.35 per cent in the FHR Series sibships.

9. The mean total longevity (realized and expected) for the 2183 members of the sibships to which the nonagenarians and centenarians belong is 63.88 years per person, which is 14.64 years more than the expected mean duration of life at birth according to the standard life table used for comparison. The corresponding figures for the 906 members of the FHR Series sibships is 47.62 years, or 1.62 years less than the life table expectation of life at birth, an insignificant difference.

10. Comparing the two groups here dealt with it appears that each additional 3.7 years in mean TIAL per pedigree has associated with it one additional year in mean duration of life of the offspring, and this without any allowance or correction whatever for accidental deaths.

11. All possible homogamic longevity correlations in the ancestry of both groups were investigated. The coefficients were generally too low to be of any practical significance, and furthermore, varied widely among themselves.

12. The same was true of the kinship (ancestral) longevity correlations within each group.

13. In the group of nonagenarians and centenarians, 41.4 per cent are moderate drinkers. This is 4.1 per cent *more* than was found in a random sample of the general population of average longevity. Furthermore 3.7 per cent of the nonagenarian and centenarian males are heavy drinkers. While this percentage is less than that of heavy drinkers in the sample of the general population with which they were compared, it is significant that there are as many as 3.7 per cent of these extremely longevous males who have been heavy drinkers. The evidence from this study clearly indicates that the moderate use of alcoholic beverages throughout life is not incompatible with the attainment of great longevity.

14. More than half (56.6 per cent) of the nonagenarian and centenarian group were total abstainers, as compared with 45.3 per cent in the sample of the general population used for comparison.

15. There is no evidence of discontinuous variation in the distribution of TIAL, or in the distribution of ages at death of any one of the six immediate ancestors of the *propositi* in either group.

Taking all the evidence presented in this study as a whole it would seem to leave no doubt as to the importance of heredity in the determination of the longevity of the individual human being. Comparison of the two groups of persons here dealt with shows that for every year of superior longevity realized by the longevous group (and their sibs) there is a corresponding superiority in the longevity of their immediate ancestors, not so large in amount to be sure because the principle of regression operates, but still real and larger than can be accounted for by chance fluctuations of sampling. Furthermore this result appears in spite of the fact that no allowance or correction has been made at any point for accidental deaths. Failure to make any such allowance or correction plainly works *against* the expression of any hereditary factor in longevity. In short the hereditary influence in longevity shown in this study is stated quantitatively as a minimum for the actual families concerned.

The data presented in this study do not, in our opinion, permit the formation of any critical judgment as to the mechanism of the inheritance of longevity, or even as to whether it is Mendelian in nature or otherwise. We are of the opinion that really critical evidence on this point cannot be derived from the purely mathematical procedure of fitting complex Mendelian formulas to statistical data of the sort presented here, or elsewhere available in such studies as have hitherto been made on the problem. After such a mathematical procedure has been successfully carried out it proves nothing more than that it has been carried out successfully. It demonstrates nothing whatever as to the *reality* of the mechanism postulated. It merely shows that the observed results *may have been due* to the postulated mechanism. But showing that a phenomenon *may have been* caused by *X* is a wholly different matter than showing that it *was* caused by *X*.

We are by no means of the opinion that it is inherently or necessarily impossible to discover and critically prove the existence of a Mendelian mode of inheritance of longevity in man, if it really does exist. On the contrary our program of investigation is definitely planned towards such an end. But it will be necessary to resort to a different kind of evidence than that presented in this, or any other similar statistical study. We believe that we have in the archives of our laboratory material that will furnish the necessary kind of evidence, and in due time we hope to be able to analyze it from this point of view. But in the meantime we are endeavoring to maintain a completely open and sceptical mind as to the ultimate outcome. We find ourselves, in short, in complete agreement with Russell⁶⁸ in the opinion that there is as yet no compelling reason to suppose that *all* phenomena of heredity in the organic world necessarily follow the Mendelian plan. From one point of view Russell states the case compactly in the following passage (pp. 68-9):

The extension of the Mendelian principle to characters other than those which can be studied in actual crosses is of course based on the general conception that the chromosomes constitute the physical basis of heredity. The argument runs somewhat as follows. The Mendelian factors are certainly borne by the chromosomes, and their behaviour can be interpreted by what we know of the distribution of the chromosomes in maturation, reduction, and fertilization. The chromosomes

⁶⁸ Russell, E. S. *The Interpretation of Development and Heredity. A Study in Biological Method.* Oxford (Clarendon Press) 1930. Pp. [4 leaves] + 312.

appear to be the only possible vehicle for the transmission of the characters of the organism as a whole, since they are the only equivalent structures in the male and female gametes, and the contribution of both parents to the hereditary equipment of the offspring appears to be equal. Hence it would seem that what is true of one set of characters should be true of the others, since all are borne by the chromosomes. We arrive therefore at the conception of a genetic constitution, consisting of a large number of factors, like those demonstrated by Mendelian research, and responsible between them—with the coöperation of the cytoplasm and of environmental conditions—for the inheritance and development of all the characters of the organism.

There is, however, contained in this argument a curious *petitio principii*, which has as a rule escaped notice, though recently it has been pointed out by Winkler. The logical slip is the assumption that the paternal and maternal contributions are of equal importance. For how can this be proved? In all breeding experiments we can deal only with differences, and only with such differences as are not incompatible with fertile inter-crossing. The great bulk of characters is necessarily common to both parents, and about each parent's contribution to the inheritance of what is common to both, breeding experiments can obviously tell us nothing. Experimental work can deal only with the inheritance of minor characters or of minor variations of major characters. Accordingly, so far as the facts go and strict logic carries us, inheritance of the main characters might be purely maternal, and involve not only the nuclear apparatus but very intimately the cytoplasm, which is practically absent in the majority of male gametes. The facts under consideration do not of course prove this unilateral inheritance, but they can certainly not be used to demonstrate that the main characters are derived in approximately equal measure from both parents. This being so, the logical argument for the extension of the gene theory to *all* characters of the organism falls to the ground, and the question remains completely open.

Here then is the point of Johannsen's suggestion, that in addition to all the separable, mendelizing characters, which can be treated in terms of separate factors, there must be postulated a "great central 'something,' as yet not divisible into separate factors." That it will ever be so divisible seems highly improbable.

We must conclude then, until further evidence is forthcoming—if it ever is—that the scope both of the Mendelian principle and of the gene theory is limited to such rather superficial variations as can be dealt with by experimental breeding. The direct contribution which genetic experiment and genetic theory make to the main problem of heredity—the reproduction of specific type, apart from minor deviations—is therefore a strictly limited one; the fundamental problem is in fact hardly touched.

Many years ago, when the modern gene theory was still in its earliest infancy, one of us made essentially the same point⁶⁴ as is now made by Russell. The passage will bear quotation here (pp. 7-8):

. two definite inferences are not only plain, but indeed inescapable. They are:

1. That germinal substance is innately possessed of a definite and particular *specificity*, which reaches, in degree, to the order of the individual, and which finds its most obvious objective expression in the specificity of somatogenesis; and
2. That the processes of reproduction are of such a sort as to tend to maintain this specificity from generation to generation.

In the light of this summary analysis of elementary facts it seems clear that *the critical problem of inheritance is the problem of the cause; the material basis; and the maintenance of the somatogenic specificity of germinal substance.*

. there are clearly to be distinguished different orders or degrees of the somatogenic specificity of the germinal substance. This fact has led to a good deal of confusion in the use of the term "heredity." For example, it is no doubt entirely correct to say that birds have feathers because this sort of dermal covering is hereditary in the class of animals specified. But heredity in this sense means, both theoretically and practically, a very different thing than when the equally true statement is made that a Barred Plymouth Rock female inherits the barred color pattern of her feathers from her sire only, and not at all from her dam. In the first case one is dealing with a phyletic matter, in the other case with a sub-variatal. It is obvious that the degrees of germinal specificity which determine the two sorts of hereditary phenomena indicated in the example must be of widely different orders. One represents the substratal or general element of heredity, the other the more superficial or individualistic element. It is obvious that the number of distinguishable different orders of germinal specificity is as great as the number of distinguishably different orders of variability, which in turn is more or less closely reflected in the various subdivisions or stages in taxonomic classification.

Longevity (duration of life) would appear to be biologically a rather fundamental attribute of the organism. Indeed it may reasonably be regarded as a single numerical expression of the integrated effects of all the forces that operate upon the individual, innate and environmental. It not only may be, but is in fact, affected adversely or favorably by environmental circumstances of the most varied sorts,⁶⁵ but also it is

⁶⁵ Pearl, R. *Modes of Research in Genetics*. New York (Macmillan) 1915. Pp. viii + 182.

⁶⁶ For a variety of experimental and statistical evidence on this point see the following two books by R. Pearl: *The Rate of Living*. New York (Alfred Knopf) 1928. Pp. [8 leaves] + 185; *Studies in Human Biology*. Baltimore (Williams and Wilkins Co.) 1924. Pp. 653; and other references therein cited.

closely bound up with the biological *constitution* of the individual, and biological constitution in man is a very highly complex matter indeed.⁶⁶ These considerations, coupled with the absence of evidence for any discontinuities of variation in its expression however analyzed hitherto, lead us to maintain for the present an open mind as to whether longevity in man is really inherited according to any Mendelian theory, however complicated. Finally it is well always to remember that Mendelian inheritance is *au fond* a theory of *alternative* inheritance.

⁶⁶ Pearl, R. *Constitution and Health*. London (Kegan Paul) 1933. Pp. 97.

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