



ESTIMATION OF THE DIRECTION AND INTENSITY OF
NATURAL SELECTION IN RELATION TO HUMAN
INTELLIGENCE BY MEANS OF THE INTRINSIC RATE OF
NATURAL INCREASE

Thesis for the Degree of Ph. D.
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Carl Jay Bajema
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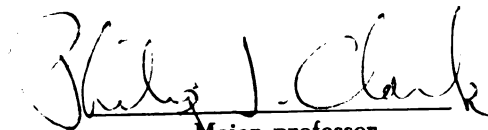
**ESTIMATION OF THE
DIRECTION AND INTENSITY OF NATURAL SELECTION
IN RELATION TO HUMAN INTELLIGENCE BY MEANS OF THE
INTRINSIC RATE OF NATURAL INCREASE**

presented by

Carl Jay Bajema

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ABSTRACT

ESTIMATION OF THE DIRECTION AND INTENSITY OF NATURAL SELECTION IN RELATION TO HUMAN INTELLIGENCE BY MEANS OF THE INTRINSIC RATE OF NATURAL INCREASE

by Carl Jay Bajema

This study was undertaken for the purpose of estimating the direction and intensity of natural selection in relation to human intelligence by means of the intrinsic rate of natural increase among 979 native-born white individuals who were born in 1916 or 1917 and who took the Terman Group Intelligence Test in the sixth grade while attending the Kalamazoo Public School System.

The average number of offspring per individual for the total sample was 2.236 and the average number of offspring per individual for the five IQ groups, ≥ 120 , 105-119, 95-104, 80-94, and 69-79, was 2.598, 2.238, 2.019, 2.464, and 1.500 respectively. The intrinsic rate of natural increase for the total sample was +0.003915. The intrinsic rate of natural increase for the five IQ groups was +0.008885, +0.003890, +0.000332, +0.007454, and -0.010001 respectively. The average generation length for the total sample was 28.49 years. The average generation length for the five IQ groups was 29.42 years, 28.86 years, 28.41 years, 28.01 years, and 28.76 years respectively. The relative fitness of the five IQ groups using e^{rm^T} as the measure of population growth was 1.0000, 0.8674, 0.7838, 0.9600, and 0.5839 respectively.

The results indicate that there is a bimodal relationship between intelligence and fertility at the present time and that this relationship is

a dynamic one. The high fertility of the $IQ \geq 120$ group relative to the other IQ groups is probably a quite recent development which has been brought about by changes in the cultural environment during the last 30 to 40 years.

The intelligence of an individual in this study was positively correlated with the number of offspring he produced ($r = +0.05$) but was negatively correlated with the size of the family from which the individual comes ($r = -0.26$). This was explained by the fact that (1) the bias inherent in the relationship between intelligence of an individual and the size of the family from which he comes tends to produce a negative relationship by itself; and that (2) the relationship between intelligence and fertility is a dynamic one.

When all of the variables that affect population growth are taken into account the population under study has probably been in equilibrium with respect to the genetic factors which favor high intelligence, or, more likely, has experienced a slight increase in the frequency of the genetic factors favoring high intelligence.

The intensity of natural selection in relation to human intelligence (the phenotypic load due to the variability in human intelligence) was found to be 0.13 in this study where the $IQ \geq 120$ group was the optimum phenotype.

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INTRODUCTION

The great changes now taking place in the social structure of human societies undoubtedly have an effect on the direction and intensity of natural selection. Whether a given human characteristic, such as intelligence, is favored or discriminated against in terms of reproductive performance may very well be a function of the social practices prevailing at the time. It is desirable, therefore, to investigate reproductive differentials in a variety of human societies at frequent intervals in order to assess the biological consequences of various social practices.

Cole (1954), in his discussion of the theoretical consequences of life history phenomena, has clearly demonstrated the necessity of taking into account the total life history pattern of the population being studied if an accurate estimation of the direction and intensity of natural selection in relation to a particular trait is to be made. The probability of making an erroneous conclusion concerning the direction and intensity of natural selection in relation to a behavioral trait such as intelligence is greatly increased if subtle differences in such factors as generation length, mortality rates, and the proportion of non-reproductive individuals are ignored. Anastasi (1956), in her review of the literature concerning the relationship between intelligence and fertility, has pointed to the fact that, since the observed correlations between intelligence and fertility are generally quite low, the operation of a very small selective factor could produce a completely spurious result.

In the past, investigators have sometimes erred in their estimates of the direction and intensity of natural selection in relation to intelligence because they failed to consider one or more of the variables which affect population growth. Differentials in the following variables must be taken into account when measuring natural selection:

- (1) Fertility (number of offspring per individual).
- (2) Proportion of non-reproductive individuals.
- (3) Mortality rates up to the end of the childbearing period.
- (4) Generation length.

The first three variables may be taken into account by including in the sample the non-reproductive individuals and those individuals who died during the period between testing and the age at which childbearing is completed and then using the method which involves the correlation of intelligence test scores of individuals with their subsequent completed fertility. However this method could possibly result in completely erroneous conclusions concerning the direction and intensity of natural selection in relation to intelligence because it does not take into account differentials in generation length. Differentials in generation length are most likely to occur in relation to behavioral traits. In fact, it is fairly certain that differentials in generation length exist in relation to intelligence.

The life table method, which involves the computation of the intrinsic rate of natural increase, provides the only means currently available whereby all of the biological variables affecting population growth can be taken into account simultaneously. During the early part of this century Lotka (1907a, 1907b, 1911, 1922, 1925) devised a statistic, r_m , now called the intrinsic rate of natural increase or the

Malthusian parameter, by which differentials in fertility, mortality, and generation length can be taken into account simultaneously when determining the growth rates of various segments of a human population. Although several biologists (Cole, 1954; Crow, 1962; Fisher, 1958) have urged the use of this statistic as a means of estimating the direction and intensity of natural selection in relation to different genotypes, it has yet to be applied to human data for this purpose.

The intrinsic rate of natural increase, r_m , provides an excellent method by which the relative importance and combined effects of fertility, mortality, and generation length of different groups of the same population can be compared. The intrinsic rate of natural increase is the geometric rate of increase that would prevail in a population if present conditions (fertility, mortality, and generation length) persisted indefinitely. We know, of course, that the present conditions will not persist indefinitely. Nevertheless, by treating biological data in the same way it is possible to obtain numerical estimates of the statistic, r_m , which can be compared with one another, thus enabling one to ascertain the relative reproductive performance of different groups within a population under prevailing conditions at a particular time.

It is the purpose of this investigation to estimate by means of the intrinsic rate of natural increase the direction and intensity of natural selection in relation to human intelligence among a group of native-born white individuals who were born in 1916 or 1917.

METHODS AND MATERIALS

Type of Population Under Study

Terman group intelligence test scores were obtained on 1144 native-born white individuals who were tested in the sixth grade by the Kalamazoo Public School System and who were born in 1916 or 1917. The average age at time of testing was 11.6 years. The study was restricted to individuals born in 1916 or 1917 because this was the youngest age group for which completed fertility data were available. It was necessary to choose all individuals born in two successive years in order to obtain a sample of sufficient size.

Data Collecting Procedures

The following life history data were collected for 979 of the 1144 individuals in the population under study: (1) data of birth; (2) number of siblings (excluding step siblings) who lived past the age of one; (3) marital status; (4) number of offspring produced who lived past the age of one; (5) date of death if the tested individual was deceased; and (6) place of residence.

The following sources of information were utilized in locating and obtaining information about the individuals included in the study:

- (1) Relatives and close friends.
- (2) Telephone directories.
- (3) City directories.
- (4) School records -- transcripts and census records.
- (5) Marriage records.

- (6) Birth records.
- (7) Death records.
- (8) Records of funeral directors.
- (9) College alumni offices.
- (10) Present and former employers.

The individuals included in the study were interviewed personally whenever possible. An attempt was made to interview in person all individuals living within a 200 mile radius of Kalamazoo. Questionnaires were sent to 77 individuals whose life histories could not be ascertained personally by the investigator.

Definitions and Formulas

The age specific rates of survival, l_x , and fertility, m_x , (where x = age in years) are defined as follows:

$$l_x = \frac{\text{number of individuals surviving to age } x}{\text{number of individuals tested}} \quad (1)$$

$$m_x = \frac{\frac{1}{2} \text{ times the number of offspring born to individuals of age } x}{\text{number of individuals surviving to age } x} \quad (2)$$

The intrinsic rate of natural increase, r_m , is the value of r which satisfies the equation:

$$\sum_{x=0}^{\infty} l_x m_x e^{-r_m x} = 1 \quad (3)$$

The average generation length, T , is obtained from the relation:

$$T = \frac{\ln(l_x m_x)}{r_m} \quad (4)$$

The relative fitness, W_i of subgroup i , is defined as:

$$W = \frac{e^{r_{mi} T}}{e^{r_{mh} T}} \quad (5)$$

where e is the base of Napierian logarithms, T is the average generation length for the total sample, r_{mi} is the intrinsic rate of natural increase for the i th subgroup of the sample, and r_{mh} is the intrinsic rate of natural increase for the subgroup of the sample having the fastest growth rate (i.e., the largest value of r_m).

The estimate of the population growth rate per individual, $e^{r_m T}$, is derived from the relationship:

$$N_t = N_0 e^{r_m T}$$

where N_t is the number of individuals alive at time T , N_0 is the number of individuals alive at time 0, r_m is the intrinsic rate of natural increase calculated by equation (3), and T is the average generation length of the total sample calculated by equation (4). If N_0 is taken as unity, then $e^{r_m T}$ is the population growth rate per individual for a period of time which is equal to the average generation length of the total sample.

The intensity of phenotypic selection in relation to a trait is defined as:

$$I = 1 - \frac{\bar{W}}{W_0} \quad (6)$$

where $\bar{W}$ is the fitness of the total population under study and W_0 is the fitness of the optimum phenotype.

RESULTS

Characteristics of the Sample

Life histories were compiled on 979 (85.6%) of the 1144 native-born white individuals in the population under study. This included 72 individuals who died before reaching the age of 45 as well as 61 individuals out of 77 individuals who were contacted by mail.

The average test score of the sample was 101.46 IQ points and the standard deviation of a random observation was 12.66 IQ points. The 979 individuals had 2189 offspring who lived past the age of one or an average of 2.24 offspring/individual. The raw data for fertility in relation to intelligence are given in Appendix I.

Possible Biases

The sample was taken at random from the population under study only in so far as the methods (see pages 4-5) used to locate individuals were unbiased. The sample was compared with the population from which it was taken to determine the presence and/or the importance of three types of biases: (1) differences in the sex ratio; (2) differences in the distribution of IQ scores; and (3) differences in place of residence (living in Kalamazoo County versus living outside of Kalamazoo County).

It was thought that females might be underrepresented in the sample because they change their last names at time of marriage. Table 1 which gives the sex ratios of the population under study and the sample clearly indicates that the sample is not biased in relation to the sex ratio.

Table 1

SEX RATIO OF THE POPULATION UNDER STUDY AND OF THE SAMPLE

	<u>Male</u>	<u>Female</u>
Population Under Study	575	569
Sample	493	486

Table 2

PROPORTION OF INDIVIDUALS IN POPULATION UNDER STUDY
INCLUDED IN SAMPLE IN RELATION TO IQ

<u>IQ Range</u>	<u>Number included in Sample</u> <u>Number in Population</u>	<u>Per Cent Included</u>
≥ 120	82/91	90.1
105-119	282/327	86.2
95-104	318/377	84.4
80-94	267/312	85.6
69-79	30/37	81.1
Total Sample	979/1144	85.6

Table 2, which gives the per cent of the original population contained in the sample with respect to the five IQ groups into which the sample was broken down, shows that the inclusion of an individual in the sample was not a function of his intelligence test score.

The sample is definitely biased with respect to place of residence. Since it can be safely assumed that almost all of the 165 individuals not contacted do not reside in Kalamazoo County, the bias in the average number of offspring per individual due to place of residence might adversely affect any conclusions concerning the relationship between intelligence and fertility. A 2 X 5 analysis of variance with disproportionate subclass numbers, as discussed by Snedecor (1956), was used to test the effect on fertility of the two residence categories within the five IQ groups (Table 3). This analysis indicated that the effects on fertility due to place of residence and interaction between place of residence and IQ were negligible.

Thus it can be concluded that the sample of 979 individuals does not deviate significantly from the population in terms of sex ratio or test score distribution and that the average number of offspring per surviving individual is not significantly different for place of residence within the five IQ groups.

Table 3

AVERAGE NUMBER OF OFFSPRING PER INDIVIDUAL SURVIVING TO AGE 45 BY PLACE OF RESIDENCE IN RELATION TO IQ

IQ Range	Living in Kalamazoo County		Not Living in Kalamazoo County	
	Number	Average Number of Offspring	Number	Average Number of Offspring
≥ 120	32	2.56	47	2.66
105-119	164	2.52	99	2.09
95-104	200	2.14	92	2.05
80-94	176	2.49	71	2.73
69-79	21	1.57	5	2.00
Total Sample	593	2.35	314	2.31

Average Number of Offspring in Relation to Intelligence

The data were subdivided into five groups in relation to test scores: IQ ≥ 120 ; 105-119; 95-104; 80-94; and 69-79. These subgroupings were chosen so that (1) one of the groups (IQ 95-104) encompassed the average IQ of the sample; (2) the bimodal nature of the data would be apparent (IQ ≥ 120 and 80-94); and (3) to maintain sufficient numbers within each group without including too wide an IQ range.

The average number of offspring per individual in relation to IQ is given in Table 4. A one-way analysis of variance showed that the average number of offspring per individual for the five IQ groups is significantly heterogeneous at the 1% level of significance ($F = 4.136 > 3.32$).

Table 4

AVERAGE NUMBER OF OFFSPRING PER INDIVIDUAL IN RELATION TO IQ

<u>IQ Range</u>	<u>Number Reporting</u>	<u>Number Offspring Per Individual</u>
≥ 120	82	2.598
105-119	282	2.238
95-104	318	2.019
80-94	267	2.464
69-79	30	1.500
Total Sample	979	2.236

Further statistical analyses were performed using the Duncan Multiple Range Test (Duncan, 1955) with corrected tables (Harter, 1960). This test maintains the protection level against making a type II error (asserting that a mean comes from the same population as another mean when in reality both means come from different populations) at the same

level that it is in the Student's *t* test which protects against the type I error (asserting that the two means come from two different populations when in reality they come from the same population) at the 95 per cent level. The results are given in Table 5.

Table 5

THE IQ GROUPS WHICH WERE FOUND TO BE SIGNIFICANTLY GREATER THAN ANOTHER IN RELATION TO THE AVERAGE NUMBER OF OFFSPRING PER INDIVIDUAL USING THE DUNCAN MULTIPLE RANGE TEST

	≥120	105-119	95-104	80-94	69-79
≥120			X		X
80-94			X		X
105-119					X
95-104					
69-79					
X means significantly greater than.					

Thus it can be concluded that the average number of offspring per individual for the IQ ≥120 group is not significantly greater than that of the IQ 80-94 group, and that the average number of offspring per individual for the two highest reproductive groups (IQ ≥120 and IQ 80-94) in the bimodal relationship between IQ and fertility are both significantly greater than the IQ 69-79 group and the average IQ group (95-104) but are not significantly greater than the IQ 105-119 group.

Table 6 compares the results of this study with those of Higgins *et al.* (1962) using the IQ subgroupings employed by them in their investigation. While the results of the study by Higgins *et al.* also indicate a bimodal relationship between IQ and fertility, it is not as

pronounced as the bimodal relationship found in this study. Both studies provide strong evidence for the existence of a high reproductive rate for the IQ >130 group which is probably a quite recent development. No other previous studies have reported a bimodal relationship between IQ and fertility and it is doubtful that the biased techniques employed in the past could have completely obscured a high reproductive rate of the high IQ group.

Table 6

COMPARISON OF THE RESULTS OF THIS STUDY WITH THOSE
OF HIGGINS et al. (1962)

<u>IQ Range</u>	<u>Average Number of Offspring Per Individual</u>	
	Higgins <u>et al.</u> (1962)	This Study
>130	2.96	3.00
116-130	2.46	2.51
101-115	2.26	2.08
86-100	2.16	2.30
71-85	2.39	2.05
56-70	2.46	0.00 (based on
0-55	1.38	three
		indi-
		duals
		however)

Since both studies indicate that a bimodal relationship exists between IQ and fertility, Penrose's equilibrium model (Penrose, 1948, 1950a, 1950b), which assumes a very high reproductive rate among the low IQ groups and a very low reproductive rate among the high IQ groups, cannot be used to explain the current relationship between IQ and fertility nor any changes that could occur in the mean IQ of the population

due to this relationship. Penrose assumed that differential fertility in relation to intelligence was a permanent phenomenon. The results of Higgins et al. (1962) and this study contradict Penrose's assumptions and support the position that the relationship between IQ and fertility is a dynamic one.

Intrinsic Rate of Natural Increase in Relation to Intelligence

Life tables were compiled for each of the five IQ groups as well as for the total sample (See Appendix II). The data were programmed and the computer facilities at Michigan State University were utilized to find the value of the intrinsic rate of natural increase for each group that satisfied equation (3). The values of the intrinsic rate of natural increase for each of the five IQ groups and for the total sample are given in Table 7. The bimodal nature of the relationship between IQ and total reproductive performance (including the effect of generation length as well as fertility) is indicated by the r_m values for the IQ ≥ 120 and IQ 80-94 groups.

Table 7

THE INTRINSIC RATE OF NATURAL INCREASE AND THE AVERAGE GENERATION LENGTH IN RELATION TO IQ

IQ Range	Intrinsic Rate of Natural Increase r_m	Average Generation Length T
≥ 120	+0.008885	29.42 years
105-119	+0.003890	28.86 years
95-104	+0.000332	28.41 years
80-94	+0.007454	28.01 years
69-79	-0.010001	28.76 years
Total Sample	+0.003915	28.49 years

Cole (1954) has estimated that the value of the intrinsic rate of natural increase for man in the United States is not far from +0.03. The value for r_m for the total Kalamazoo sample was only +0.003. The fact that r_m was extremely small for this study can be explained by the characteristics of the population under study which are known to affect fertility in a negative way and thus would reduce r_m . The population under study consisted of: (1) white individuals only; (2) native born Americans only; (3) individuals with above average educational attainments; (4) predominately Protestant individuals; (5) individuals who spent almost all of their potentially most productive childbearing years during the Great Depression and World War II; and (6) individuals who spent most or all of their lives in an urban environment. The urban nature of the population under study is probably the major reason for finding such a small intrinsic rate of natural increase. It is a well known fact that the completed fertility of the total urban population (age 45 and older) of the United States has been below replacement level in the past (Grabill, 1959).

Generation Length In Relation to Intelligence

The almost universally held hypothesis that the generation length of the lower IQ groups is shorter than the generation length of the higher IQ groups has been supported by casual observations and by data compiled by Conrad and Jones (1932), who correlated the intelligence of the parent with the age of the parent at the birth of the first, second, third and fourth child and found that the age of the parent at the time of birth of his children is positively correlated with IQ (the higher the IQ, the older the parent at the time of birth of his children). However, no exact estimates concerning generation length (given in years)

in relation to IQ have been made.

Table 7 gives the average generation length, T , which was calculated from equation (4) for the five IQ groups as well as for the total sample. These results indicate a very slight positive relationship between IQ and generation length. The IQ 69-79 group is the only IQ group that deviates from this positive relationship. The average generation length for the total sample is in agreement with the estimated average generation length for the population of the United States (29-30 years).

Relative Fitness in Relation to Intelligence

Relative fitness is defined in this paper as the ratio of population growth rate per individual of a particular phenotype (IQ group) to the population growth rate per individual of the optimum phenotype (IQ group) for the same trait. The optimum phenotype is that phenotype which has the highest population growth rate per individual (IQ ≥ 120 in this study).

The relative fitness of each of the five IQ groups using the average number of offspring per individual as the measure of population growth is given in Table 8 while Table 9 gives the relative fitness of the five IQ groups using $e^{r_m T}$ which takes all the variables affecting population growth into account. Note that because the IQ ≥ 120 group had the longest generation length the relative fitness of each of the other four IQ groups is increased when $e^{r_m T}$ is used to measure relative fitness instead of the average number of offspring per individual. This indicates the importance of generation length as a variable which can affect the population growth rates of several phenotypic classes of a particular behavioural trait unequally.

As pointed out by Dobzhansky and Allen (1956), fitness is a

Table 8

RELATIVE FITNESS IN RELATION TO IQ
USING THE AVERAGE NUMBER OF OFFSPRING PER INDIVIDUAL AS
THE MEASURE OF POPULATION GROWTH

<u>IQ Range</u>	<u>Relative Fitness</u>
≥ 120	1.0000
105-119	0.8614
95-104	0.7771
80-94	0.9484
69-79	0.5774

Table 9

RELATIVE FITNESS IN RELATION TO IQ USING $e^{-r_m T}$
AS THE MEASURE OF POPULATION GROWTH

<u>IQ Range</u>	<u>Relative Fitness</u>
≥ 120	1.0000
105-119	0.8674
95-104	0.7838
80-94	0.9600
69-79	0.5839

meaningful concept only in relation to a particular environment. The relative fitness values given in this paper pertain only to the population under study and cannot be assumed to be the same for IQ groups in different environments.

Intensity of Natural Selection in Relation to Intelligence

When measuring the effect of natural selection on a trait it is of interest to determine the population's phenotypic load or the proportion by which the population fitness is decreased in comparison with the optimum phenotype. This reduction in the fitness of the population relative to the optimum phenotype is called the intensity of natural selection (Haldane, 1954; Spiess, 1962). The intensity of natural selection in this study is measured by subtracting the relative fitness of the total sample (where fitness is measured by $e^{r_m^T}$) from one (equation 6).

The intensity of natural selection in relation to intelligence in man was found to be 0.13 in this study where the optimum phenotype is the $IQ \geq 120$ group. The fitness (reproductive performance) of the population under study, therefore, is 0.13 less than what it would be if all the IQ's were in the optimum range ($IQ \geq 120$). That is to say, the phenotypic load due to variability in intelligence is 13 per cent.

Correlation Analyses

The negative relationship between the IQ of an individual and the size of the family from which the individual comes has been observed many times and is one of the major pieces of evidence used to support the hypothesis that the IQ of the population is declining. The correlation coefficient between the IQ of an individual and the size of the

completed family from which he comes is -0.2599 for this study and is significantly different from 0 at the 1 per cent level. This is in agreement with the results of other studies done on samples of a similar nature which have found the negative correlation to be between $r = -0.20$ and $r = -0.30$. However when the IQ of an individual was correlated with his subsequent completed fertility in this study the correlation coefficient is $+0.0503$ which is significantly greater than 0 at the 6 per cent level by a one-tailed test. This means that the mean IQ of the population under study has probably increased by a small amount due to the small positive relationship between IQ and fertility.

The fact that in this study the IQ of an individual is positively correlated with the number of offspring he produces but is negatively correlated with the size of the family from which he comes appears to be paradoxical at first. However these observed correlations are due to the operation of two factors.

First, the correlation between the IQ of an individual and the size of the family from which he comes has an inherent defect which makes any estimation concerning the relationship between intelligence and fertility based on it subject to considerable error. That part of the population which leaves no offspring (20.2 per cent in this study) is completely ignored. The results (Table 10) indicate that the relationship between the intelligence of an individual and the size family from which he comes is biased in a negative direction due to the fact that as intelligence decreases the probability of leaving no offspring increases. The results of this study show that the probability of leaving no offspring is more than two times as great for the IQ 69-79 group in comparison to the $IQ \geq 120$ group. A comparison of Table 10 with Table 11

Table 10

PROPORTION OF INDIVIDUALS WHO LEFT NO OFFSPRING
IN RELATION TO IQ

<u>IQ Range</u>	<u>Number</u>	<u>Per Cent Leaving No Offspring</u>
≥120	11	13.41
105-119	48	17.02
95-104	70	22.01
80-94	60	22.47
69-79	9	30.00
Total Sample	198	20.22

Table 11

PROPORTION OF INDIVIDUALS WHO NEVER MARRIED
IN RELATION TO IQ

<u>IQ Range</u>	<u>Number</u>	<u>Per Cent Never Married</u>
≥120	5	6.10
105-119	14	4.96
95-104	21	6.60
80-94	15	5.62
69-79	3	10.00
Total Sample	58	5.92

indicates that this is primarily due to differentials in childbearing as opposed to the differentials in marriage rates which were found by Higgins et al. (1962) to be the important factor in their study. The correlation coefficient between the IQ of individuals who were not childless and the number of offspring they produced was found to be $+0.0077$ which is not significantly different from 0 at the 10 per cent level, and which is a shift in the negative direction from $r = +0.0503$. Thus it can be concluded that the relationship between the intelligence of an individual and the size of the family from which he comes has an inherent bias in the negative direction at the present time.

Secondly, the relationship between intelligence and fertility is definitely a dynamic one and appears to be changing rapidly. Higgins et al. (1962) and this study have shown that a bimodal relationship exists between IQ and fertility at the present time. It is doubtful that the biased techniques employed by previous studies could have completely obscured a high reproductive rate of the high IQ group. Therefore, it is highly probable that fertility is more positively correlated with intelligence than at any time during the past 75 years. It is a well known fact that a tremendous change has taken place with respect to family size in the United States. There has been a decrease in the proportion of unmarried individuals, childless families, and one-child families in addition to a decrease in the proportion of families having five or more children (Grabill, 1959). In this study the correlation between the size of the family from which an individual comes and the number of offspring produced is quite low ($r = +0.07$). Thus a positive change in the relationship between intelligence and fertility occurring simultaneously with the great changes taking place with respect to family

size could help explain the observed positive correlation of intelligence with the number of offspring produced and the negative correlation of intelligence with the size of the family that the tested individual comes from.

Estimation of the Change in the Frequency of the Genetic Factors Favoring High Intelligence in the Population Under Study

It is generally held that a major part of the variation in intelligence is due to genetic factors which are usually considered to be primarily quantitative in nature. It is highly probable that at least 50 to 60 per cent of the total variation in intelligence is due to hereditary factors. Vandenberg (1962), for instance, has found that approximately 60 per cent of the variation in numerical, verbal, spatial, and word fluency abilities in dizygous twins is due to hereditary factors. While an estimate of the amount of change in the frequency of the genetic factors favoring high intelligence must await further elucidation of the exact factors involved, it is possible to estimate the direction of change in relation to these factors. A positive relationship between intelligence and fertility would indicate that an increase in the frequency of the genetic factors favoring high intelligence is taking place while a negative relationship would indicate that a decrease in the frequency of these factors is taking place.

The observed positive relationship between the IQ of an individual and his subsequent completed fertility ($r = +0.05$) would seem to indicate that a small but positive increase in the genetic factors favoring high intelligence has taken place in the population under study. However the negative effect of generation length (see Table 7) tends to counterbalance the positive effect due to the number of offspring produced to a

certain extent. When generation length is taken into account it has been shown that there is little difference between the relative fitness of the IQ ≥ 120 group and that of the IQ 80-94 group. This bimodal relationship between IQ and total reproductive performance complicates any estimation of the change in the frequency of the genetic factors favoring high intelligence.

It can be concluded that the population under study has been in a state of equilibrium or has actually experienced a very slight increase in the genetic factors favoring high intelligence over the one generation that the population was studied. The equilibrium or slight increase in the frequency of the genetic factors favoring high intelligence is not due to the reproductive success of the average IQ group but is due to the counterbalancing effects of the high reproductive rates of the high IQ group (≥ 120) and of the low normal IQ group (80-94).

SUMMARY

This is a follow-up study of 979 white native-born individuals who were born in 1916 or 1917 and who took the Terman Group Intelligence Test in the sixth grade while attending the Kalamazoo Public School System. It is the first study that has taken into account all of the variables that affect population growth (fertility, mortality, and generation length) by means of the intrinsic rate of natural increase when estimating the direction and intensity of natural selection in relation to human intelligence.

A bimodal relationship between intelligence and fertility was observed in this study. The high fertility of the IQ ≥ 120 group relative to the other IQ groups is probably a quite recent development which has been brought about by changes in the cultural environment during the last 30 to 40 years.

The observation that the intelligence of an individual is positively correlated with the number of offspring he produces but is negatively correlated with the size of the family from which the individual comes was explained by the fact that (1) the bias inherent in the relationship between the intelligence of an individual and the size of the family from which he comes tends to produce a negative relationship by itself; and that (2) the relationship between intelligence and fertility is a dynamic one. It is highly probable that fertility is more positively correlated with intelligence than at any time during the past 75 years.

When all the variables that affect population growth have been taken

into account the population under study has probably been in equilibrium with respect to the genetic factors which favor high intelligence, or, more likely, has experienced a slight increase in the frequency of the genetic factors favoring high intelligence.

The intensity of natural selection in relation to human intelligence (the phenotypic load due to the variability in human intelligence) was found to be 0.13 in this study where the $IQ \geq 120$ group was the optimum phenotype.

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APPENDIX I.

IQ IN RELATION TO NUMBER OF OFFSPRING PRODUCED

IQ	Number of Offspring Produced											
	0	1	2	3	4	5	6	7	8	9	10	15
69	2											
70	1											
71		1										
72	1	1										
73	1			1			1					
74		1										
75		2										
76		1	2	1								
77	2		1	1								
78		2	1				1					
79	2	1	2	1								
80		1	1	2	1			1				
81			1	2								
82	1	2	1	3								
83	1	2	4	1	1	1						
84	3	2	3	1	1	2						
85	4	1	1	1	1	1			1			
86	1	1	3		1	2						
87	5	1	7	4		2		1	2			
88	2	4	4	2	2	1	3					
89	4	2	6	3	1	2	1	1	1	1		
90	10	2	6	5	1	1	2		1			
91	7	1	8	8	5	2			1			
92	8	2	7	4	2	2	1		1		1	

APPENDIX I. Continued

IQ	Number of Offspring Produced											
	0	1	2	3	4	5	6	7	8	9	10	15
93	8	5	10	5	5		1		1			
94	6	2	5	5	4	2			2			
95	11	7	11	4	4							1
96	5	2	10	6	3	1		1				
97	8	8	6	9	5	2	1	2				
98	2	4	10	4	1							
99	5	5	9	2			1	1				
100	14	5	17	10	7	2	2					
101	6	2	4	6	2	2		1				
102	5	6	10	1	3							
103	3	4	13	4	1							
104	11	7	9	3	5		1		1			
105	6	2	12		2	1						
106	3	4	13	6	4		1	2				
107	5	5	8	7	2	3						
108	7	1	6	5	2	2						
109	4	4	6	1	4		1					
110	3	10	7	3	3	1			1		1	
111	2	5	3	6	4							
112	5	5	7	5		3		1				
113	4	1	3	3	1			1				
114	2	2	5	1	1		1					
115	1	1	1	1	1							
116	2	3	4	1	4							
117	1		3	4	2							

APPENDIX I. Continued

IQ	Number of Offspring Produced											
	0	1	2	3	4	5	6	7	8	9	10	15
118	1	2	2	2		1	2					
119	2	2	3	3	1	1	1		1			
120		3	4	2	1							
121		2	2	2	2	1						
122	2	1	3	1	1							
123			1	2	1	1						
124	1		2	2								
125	1		1	4	1	1						
126	2	1	1			1						
127			1									
128			3	2								
129							1					
130			1		1							
131			2	1		1						
132	2											
133			1	1			1					
134	1				1							
135	1											
137			1	1								
138					2							
140	1											
141					1							
143					1							
146								1				
147						1						
151					1							
164						1						

APPENDIX II

LIFE TABLE FOR THE TOTAL SAMPLE

x	l_x	m_x
14	0.99694	0.00051
15	0.99387	0.00051
16	0.99081	0.00052
17	0.98774	0.00879
18	0.98570	0.01295
19	0.98161	0.02862
20	0.98161	0.03538
21	0.97957	0.04588
22	0.97753	0.05277
23	0.97651	0.05753
24	0.97446	0.06342
25	0.97344	0.07870
26	0.96936	0.07271
27	0.96323	0.06734
28	0.95608	0.07265
29	0.95097	0.08002
30	0.94995	0.07581
31	0.94893	0.06297
32	0.94893	0.05544
33	0.94688	0.05124
34	0.94586	0.04104
35	0.94484	0.03946
36	0.94178	0.02983
37	0.93973	0.02283
38	0.93871	0.02394
39	0.93871	0.02503
40	0.93769	0.02288
41	0.93667	0.01418
42	0.93258	0.01150
43	0.93156	0.00658
44	0.92850	0.00330
45	0.92646	0.00110

LIFE TABLE FOR THE IQ ≥ 120 GROUP

x	l_x	m_x
14	1.00000	0.00000
15	1.00000	0.00000
16	1.00000	0.00000
17	1.00000	0.00000
18	1.00000	0.00000
19	1.00000	0.00610
20	1.00000	0.03659
21	1.00000	0.02439
22	1.00000	0.04268
23	1.00000	0.07317
24	1.00000	0.05488
25	1.00000	0.08537
26	0.98780	0.11111
27	0.98780	0.09877
28	0.98780	0.08642
29	0.98780	0.12963
30	0.98780	0.10494
31	0.98780	0.05556
32	0.98780	0.03704
33	0.98780	0.04321
34	0.98780	0.04938
35	0.98780	0.03704
36	0.97561	0.03750
37	0.97561	0.02500
38	0.96341	0.03165
39	0.96341	0.05696
40	0.96341	0.03165
41	0.96341	0.01899
42	0.96341	0.02532
43	0.96341	0.00633
44	0.96341	0.00000
45	0.96341	0.00633

LIFE TABLE FOR THE IQ 105-119 GROUP

x	l_x	m_x
14	1.00000	0.00178
15	0.99645	0.00000
16	0.99291	0.00000
17	0.98936	0.00717
18	0.98936	0.01075
19	0.98582	0.02518
20	0.98582	0.03777
21	0.97872	0.03080
22	0.97518	0.04182
23	0.97518	0.05273
24	0.97518	0.05818
25	0.97163	0.07482
26	0.96809	0.07509
27	0.96454	0.07169
28	0.95390	0.07993
29	0.94326	0.09023
30	0.94326	0.07519
31	0.93972	0.06981
32	0.93972	0.06038
33	0.93617	0.05114
34	0.93617	0.03788
35	0.93617	0.04924
36	0.93617	0.02841
37	0.93262	0.03612
38	0.93262	0.01711
39	0.93262	0.02471
40	0.93262	0.03042
41	0.93262	0.01521
42	0.93262	0.00951
43	0.93262	0.00570
44	0.93262	0.00380
45	0.93262	0.00000

LIFE TABLE FOR THE IQ 95-104 GROUP

x	l_x	m_x
14	0.99686	0.00000
15	0.99686	0.00158
16	0.99057	0.00159
17	0.98742	0.01433
18	0.98428	0.01438
19	0.97799	0.02733
20	0.97799	0.03215
21	0.97799	0.04662
22	0.97484	0.05806
23	0.97170	0.04045
24	0.97170	0.07282
25	0.97170	0.06958
26	0.96541	0.06026
27	0.95912	0.04918
28	0.94969	0.06623
29	0.94654	0.06478
30	0.94654	0.06146
31	0.94654	0.05648
32	0.94654	0.05814
33	0.94654	0.05150
34	0.94654	0.04319
35	0.94654	0.02492
36	0.94340	0.02667
37	0.94340	0.02000
38	0.94340	0.02667
39	0.94340	0.01500
40	0.94025	0.01171
41	0.93711	0.01510
42	0.93082	0.01520
43	0.92767	0.00508
44	0.92138	0.00171
45	0.91824	0.00171

LIFE TABLE FOR THE IQ 80-94 GROUP

x	l_x	m_x
14	0.99251	0.00000
15	0.98876	0.00000
16	0.98127	0.00000
17	0.98127	0.00573
18	0.98127	0.01336
19	0.97753	0.04406
20	0.97753	0.04023
21	0.97753	0.06897
22	0.97753	0.06322
23	0.97753	0.07854
24	0.97378	0.06154
25	0.97378	0.09231
26	0.97378	0.08077
27	0.96255	0.07004
28	0.95880	0.07227
29	0.95506	0.07843
30	0.95131	0.08858
31	0.95131	0.06890
32	0.95131	0.05906
33	0.94757	0.05138
34	0.94757	0.03953
35	0.94382	0.04960
36	0.94382	0.03571
37	0.94007	0.00996
38	0.94007	0.02789
39	0.94007	0.02789
40	0.94007	0.02590
41	0.94007	0.00996
42	0.93258	0.00602
43	0.93258	0.01004
44	0.92884	0.00202
45	0.92509	0.00000

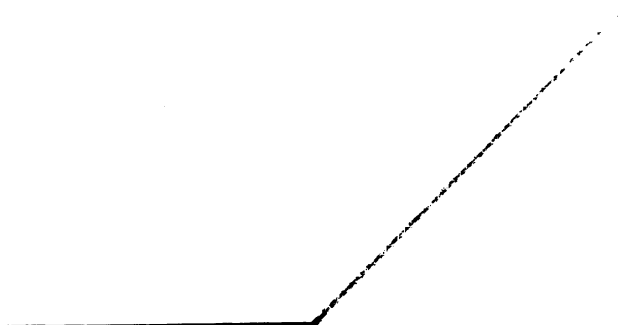
LIFE TABLE FOR THE IQ 69-79 GROUP

x	l_x	m_x
14	1.00000	0.00000
15	1.00000	0.00000
16	1.00000	0.00000
17	1.00000	0.01667
18	0.96667	0.05172
19	0.96667	0.00000
20	0.96667	0.00000
21	0.96667	0.03448
22	0.96667	0.03448
23	0.96667	0.05172
24	0.93333	0.05357
25	0.93333	0.07143
26	0.93333	0.00000
27	0.93333	0.10714
28	0.93333	0.03571
29	0.93333	0.01786
30	0.93333	0.03571
31	0.93333	0.03571
32	0.93333	0.00000
33	0.93333	0.07143
34	0.90000	0.03704
35	0.90000	0.01852
36	0.86667	0.00000
37	0.86667	0.03846
38	0.86667	0.00000
39	0.86667	0.01923
40	0.86667	0.01923
41	0.86667	0.01923
42	0.86667	0.00000
43	0.86667	0.00000
44	0.86667	0.03846
45	0.86667	0.00000

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