Intelligence: genetic and environmental influences

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chapter 10

a tale of two thermos bottles: properties of a genetic model for human intelligence

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Mr. Smith, a native-born American in Florida, has a thermos bottle and uses it exclusively for keeping cold drinks cold. Mr. Li, a Chinese residing in Peking, also has a thermos bottle but uses it exclusively for keeping hot water hot. In fact, the thermos bottle is known by the name "hot water bottle" in China and it has never occurred to the Chinese that it also can keep cold things cold, as he has never had an occasion to use it that way. [162]

If we have no knowledge about the transfer of heat and the principle of insulation by vacuum, it would look as if there are two different kinds of bottles with two opposite functions; hence, it requires two sets of reasons to explain the two observed phenomena. To be sure, it is not difficult at all to point out the many differences between the two bottles. We may note that they are different from the very beginning; one is made in New Jersey and one in Tientsin. Maybe the two manufacturing processes are different. Certainly the outside designs are strikingly different. I do not propose to belabor this point unduly. Suffice it to say that these differences exist and are real, but they are not the reasons why one bottle keeps cold things cold and one keeps hot things hot. It is only through physical studies that we recognize that these are not two opposite phenomena but one and the same phenomenon, to be explained by one reason, [163] not by many different reasons. This is the nature of a scientific explanation. One basic principle explains various and sometimes apparently contradictory phenomena, thus unifying our knowledge in an orderly manner.

Early environmental influences

As to the differences among individuals and among racial groups, many authors tend to attribute them to early environmental differences for such individuals or groups. This is undoubtedly true for certain traits – but certainly not for all traits. As an example, let us consider the red-green color blindness among females and males. It has been known for many decades that there arc more color-blind boys than girls. If we disregard for the moment the modern explanation for the sexual difference in color blindness, how did the "scientists" before, say, 1900 explain the phenomenon?

They did have explanations, very good ones too. Males and females have different attitudes toward color in general. When buying a new car, a young man would ask about the things under the hood; a young woman would ask. "What color is it?" In the old days (not too long ago actually) girls used to sew and embroider with colorful threads. They have early contacts with color, upon which their beauty depends so much. The boys used to ride on horses, play ball, practice fencing, or engage in some other physical activities, none of which is related to color. The difference between between boys and girls in their early contacts with color and the difference in value they attach to color exists and is real. Hence, there are more boys than girls who never learned to distinguish certain colors. This explanation, based on early environmental conditions, sounds perfectly reasonable and is even appealing in many respects except one–it is untrue.

The case of color blindness brings out an extremely important general principle in logical, research; viz., the demonstration of the existence of an environmental difference does not automatically mean that it is the cause for the difference in the characteristics under study. To demonstrate that a certain factor is the cause for certain characteristics requires an independent and much more laborious research. The modern explanation for color blindness is based on a large number of detailed family pedigrees, and its predictive accuracy has been confirmed by all known families.

Two opposite phenomena

A topic that frequently arises among my Chinese friends is why the offspring generation of these academic Chinese (from China) are not doing as well as their fathers, or at least, do not seem to be doing as well. The performance of the offspring generation causes real anxiety for the fathers, as judged from the seriousness with which they discuss the problem. Are the Chinese deteriorating? If so, why? Most of [164] these Chinese are natural scientists and engineers and have considerable accomplishments in their own fields. They figured (originally) that their sons would be able to do better than themselves because of the more favorable educational and social factors for the young generation. The young do not have language difficulties and no accent, while almost all of the fathers speak English with an accent. (A few of them are hardly understandable.) Moreover, the young have better nutrition and better schooling in this country and seem to be in good health. Their fathers' early environment in China, by our present standard, would be described as nothing less than deprivation. If the young Chinese generation were doing better than their fathers, then the influence of these social factors would be accepted as reasonable explanations. But, actually, they do not seem to be doing as well. How do we account for it?

Fortunately, we shall never run out of social and environmental factors that may be invoked to explain any phenomenon. In this particular case there are presumably social factors working against the younger Chinese generation. The many reasons offered to me vary from one level to another. On the national level, one may point to the softer life in the United States. Their fathers had to struggle to survive; they had no doubt in their minds that if they did not study hard there would be absolutely no future for them. The younger generation, born and raised in this country, have taken life for granted and do not share that sense of urgency. On the individual level, one says that the fathers work too hard and do not play enough with their children, who thus do not develop well; everything about the child has been determined in the first four years of his life. Or, one may say that the fathers are so brilliant that they have completely overshadowed their children, who are thus suffering from a severe psychological handicap. And many other faults on the part of the parents, especially the father, are offered.

However, in order to show that these unfavorable factors are responsible for the comparatively inferior performance of the offspring generation, we need to show that they are stronger than the favorable factors existing at the same time. How are we to weigh them, even relatively? What complicates the matter further is that there is a group of Chinese whose offspring are doing better, much better, than their fathers. This is the group of Chinese laborers (e.g., laundry men). Many of their children are now professionals and are no longer part of Chinatown. To explain this phenomenon, one may cite again the favorable factors (English, school, health, etc.) mentioned previously and conveniently forget the unfavorable factors (soft life, etc.), apparently assuming that the laundry-men fathers play a great deal with their children. Another pseudoscientific argument is: Where can they go but up? Well, they can be unemployed and go on charity; they do not have to go up at all.

We have observed two directly opposite phenomena: (1) the children of the group of Chinese of high achievements tend to have lower achievements than their fathers, and (2) the children of the group of Chinese of low achievements tend to have higher achievements than their fathers. To [165] explain the two opposing trends in terms of social factors alone, we are forced to keep in storage a large number of social factors, including favorable and unfavorable ones of various degrees, and pull out the right one to fit the right occasion. Then, the explanation is necessarily a posteriori ("Monday morning quarterback"), deficient in analytical foundation, lacking in predictive value, and not applicable to other cases.

Need for a unified explanation

What we need is a unified explanation for the two apparently opposing trends described in the previous section. As in the case of the two thermosbottles, the ability to keep cold things cold and the ability to keep hot things hot are not to be considered as two opposing abilities but one and the same phenomanon to be explained by only one reason (insulation in this case) rather then by various incidental reasons. Hence, we shall seek a mechanism which, if it explains why the children of Chinese with high academic accomplishment tend to do worse than their fathers, would also explain why the children of Chinese with low academic accomplishment tend to do better than their fathers With such a mechanism these two trends will be considered as one and the same phenomenon, to be explained by only one reason and not by many different incidental reasons.

The usual statistical term describing the phenomena is regression. The statistician says that the average value of a quantitative trait of the offspring of parents of either very high or very low value tends to "regress" toward the average value of the population as a whole. But this is merely a paraphrase of what we have been saying all along. Regression describes the fact quantitatively but does not explain why. Descriptive statistics seldom reveals the underlying mechanism for a phenomenon. Even as a descriptive tool, the phrase "regression toward the mean" is not the whole story and may easily mislead one to think that there will be more and more individuals in the middle range and fewer and fewer individuals in the extreme categories in subsequent generations – which is, of course, not the case. For most quantitative traits the distribution (its form, if not its position) is quite stable and remains very nearly the same from generation to generation. Unless measured in an evolutionary time scale, the difference among a few successive generations is not detectable by our usual sample studies. For all practical purposes we may assume that the population is in a stationary state. At this point, it should surprise nobody that the writer, a geneticist, shall propose a genetical model to explain the two opposing trends.

Atypical pedigrees

Before outlining my population genetical model, I shall first
clear up a possible misunderstanding of hereditary phenom- [166]
ena for which the overenthusiastic human geneticists themselves are partially responsible. The extraordinary pedigree involving Francis Galton and Charles Darwin, who were first cousins, is often cited to illustrate the heredity of mental ability in man. However, not every member of this prominent pedigree exhibits the same kind of mental ability. Moreover, the pedigree taken as a whole can also be explained by common favorable environments and chance appearance. This type of pedigree is of more historical interest than of scientific significance. To prove that a certain type of mental ability has a hereditary component involves more than producing a very rare pedigree that represents an exception rather than a rule. If the mental ability is hereditary, what should we expect to see from all pedigrees? This is a more appropriate question.

Historically, another and even more extreme pedigree is often cited to demonstrate the heredity of mental ability; it is the pedigree of the celebrated family of mathematicians –
the Bernoullis. Since the idea of the heredity of mathemati- [167]
cal ability, like that of musical ability, is more tolerable to the social scientists, I shall use the Bernoulli family (Figure 1) to illustrate why I object to using rare pedigrees as a proof of heredity.

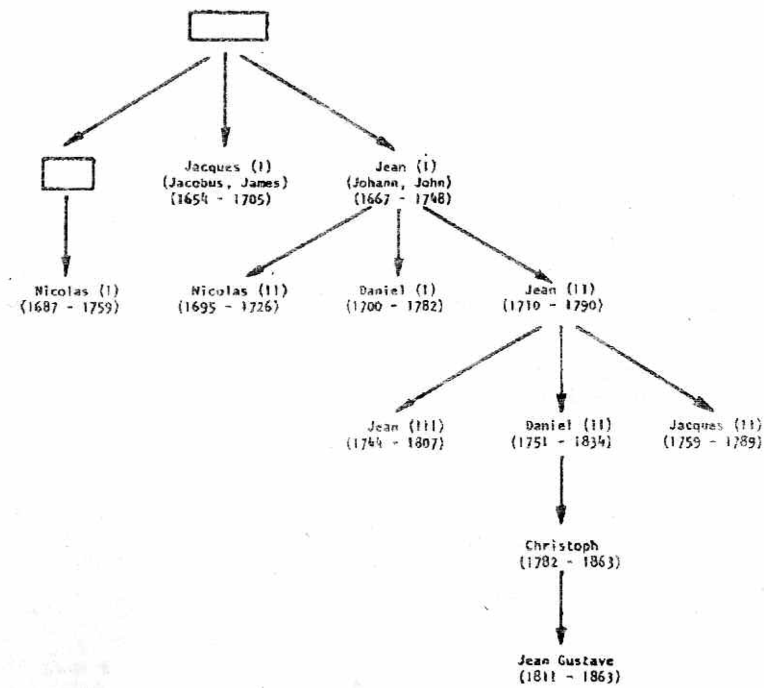


Figure 1. Simplified pedigree of the Bernoulli family. Only mathematicians are shown in the diagram.

The fame of the mathematical family began with Jacques Bernoulli, usually designated as Jacques (I) by historians to distinguish him from another Jacques Bernoulli (II) two generations later. We cannot mention here his many mathematical contributions, which are truly great. He was the fifth child of the family. His younger brother, Jean (I), was the tenth child of the family and thirteen years his junior; but Jean turned out to be even more prolific than Jacques. Nicolas (I), a nephew of Jacques and Jean, was also a prominent mathematician. Three of Jean's sons achieved fame in mathematics. especially Daniel. Jean (II), the son of Jean (I), again had accomplished mathematician offspring. The later Bernoullis (Daniel II, Jacques II, Christoph, etc.) were also professional mathematicians but did not achieve first-class fame in history. Christoph's son, Jean Gustave, was also a mathematician.

If the pedigree of the four or five generations of mathematicians is impressive from the hereditary point of view, their family attitude is even more interesting from the environmental point of view. One would think that at least part of the mathematical tradition is due to familial environment such as the early influence of the fathers. This was not the case in the Bernoulli family. The father of the original Jacques and Jean was emphatically opposed to their study of mathematics, placing all possible obstacles in their way. After his failure to make Jacques a theologian, the father determined to make Jean a merchant and failed again. One may argue that the father, not being a mathematician, may not have influenced his sons, but his sons, being mathematicians, must have influenced the later generations. This does not seem to be true either. Jean (I), the most prolific mathematician of the Bernoulli family, had the same attitude toward mathematics as his own father, and he tried to force his own son, Daniel (I), to become a businessman. Daniel disappointed him as he had his father.

If we use the unbroken array of mathematicians over four generations in a family as a proof of heredity of mathematical ability, then what can we say about the families in which there is no such array of mathematicians? Cannot one argue that if such an array is absent, then the mathematical ability has no hereditary component? Since the great majority of families do not have such an array of mathematicians, the social scientists are perfectly entitled to be skeptical of the theory of heredity of mathematical ability. The main source of confusion is that the extraordinary pedigree outlined in Figure 1 represents a misleading rare event rather than the usual pattern that we expect of a hereditary quantitative trait. Heredity does not mean "like begets like." The relationship between parents and offspring as depicted in Figure 2 are very wrong for a human population. As will be illustrated in the next section, even if a trait is entirely determined by a few genetic factors, the variation in the offspring [168]
of any family will still be quite wide. Hence, a proper presentation of the hereditary pattern can only be achieved by the appropriate methods of population genetics.

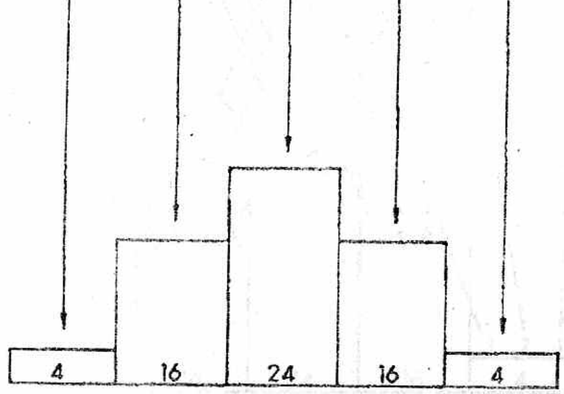


Figure 2. Wrong conception of heredity in a human population. Only very rigid social forces can make "like beget like."

Genetic model for quantitative traits

By way of illustration I shall outline the simplest genetic model for quantitative traits, ignoring the environmental effects for the time being. Suppose that a certain type of mental ability (e.g., intelligence, mathematics, music, etc.) is determined by two pairs of genes, (A, a) and (B, b). Although this is too simple to be realistic, it will show the general pattern of the hereditary phenomenon clearly. To further simplify our calculation, let us assume that the effects of these two pairs of genes are of the same magnitude, which we may take as unity. That is, we shall assign a value of 1 to each of the capital letters and 0 to each of the lower-case letters of each genotype. We also assume that the effects of the two pairs of genes are additive; i.e., the effect of one gene pair is to be added to that of the other. With this [169]
simple model the values of the quantitative trait for the nine genotypes are as follows:

Genotypes	aabb	Aabb aaBb	AAbb aaBB AaBb	AABb AaBB	AABB
Value	0	1	2	3	4

The point 0 in the scale above is an arbitrary origin. To reduce the arithmetic labor to almost nothing, we assume that the gene frequencies are all equal to one-half; i.e., freq(A) = freq(a) = ½ and freq(B) = freq(b) = ½. Then in a random-mating stationary population, such as ours, the distribution of the values of the quantitative trait is as follows:

Value	0	1	2	3	4	Total
Frequency	1	4	6	4	1	16
or	4	16	24	16	4	64

We shall use the numbers 4, 16, 24, and so on for convenience, remembering that their common denominator is 64. If this is the parental generation, what would be the offspring generation? What are the relationships between the various classes of parents and those of their offspring? It should be reiterated that the relationships between parents and offspring in a random-mating population are not like those shown in Figure 2. The correct pattern of parent-offspring relationships is shown in Figure 3.

Before we consider Figure 3 in detail, a few words about the method of constructing the diagram might be helpful. Consider the parent genotype Aabb (value 1) which produces ½ (Ab) and ½ (ab) gametes. In a random-mating population these gametes will unite with gametes (AB), (Ab), (aB), (ab) each with frequency ¼. Hence, the offspring of the

Aabb parent will be of the following genotypes (the number below the genotype is the value of the quantitative trait of that genotype):

	(AB)	(Ab)	(aB)	(ab)
(Ab)	AABb 3	AAbb 2	AaBb 2	Aabb 1
(ab)	AaBb 2	Aabb 1	aaBb 1	aabb 0

Collecting the genotypes according to their quantitative values, we have the following distribution: [170]

Value	0	1	2	3	4	Total
Frequency	1	3	3	1	0	8

A similar situation exists for the parent aaBb. Therefore, the class of parents with value 1 (Aabb and aaBb) and total frequency 16 will yield offspring of values 0, 1, 2, 3 with frequencies 2, 6, 6, 2, respectively, with an average value of 1.50. All other connecting lines in figure 3 are calculated the same way.

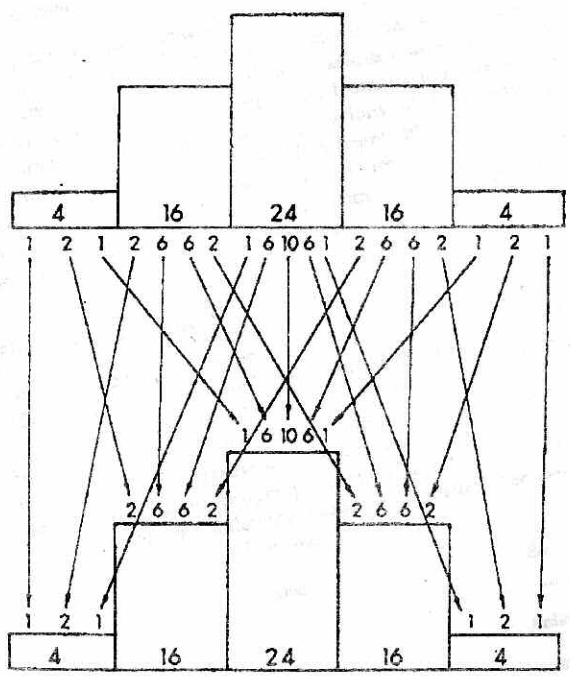
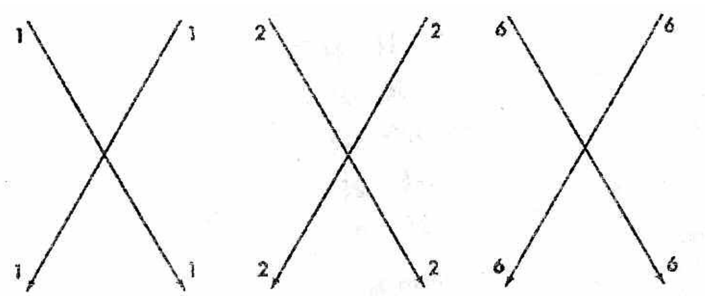


Figure 3. The connections between two random-mating generations.

A careful study of the network connecting parents and offspring is worthwhile. The diagram explains almost every question we have raised before. In particular, it shows that the children of parents of high value have a lower average value than their parents and that the children of parents of low value have a higher average value than their parents.

For instance, parents of value 4 (extreme right-hand class in [171] Figure 3) will have offspring of values, 2, 3, 4 with frequencies 1:2:1, respectively, resulting in an average value of 3. A similar situation exists for parents of value 0, whose children have an average value of 1.This diagram explains the apparently two opposite phenomena simultaneously by the same mechanism, viz., *random gene segregation and recombination*. The two seemingly opposite facts are actually the same phenomena of gene segregation, and we cannot have one without the other. The bottle that keeps cold things cold will also keep hot things hot. It is the same function. If the academic achievement is due partly to hereditary factors, then the two opposing phenomena observed in the American-Chinese population are natural events and expected to be so, as long as the social and environmental factors do not obliterate the effects of genetic factors completely. The observed phenomena show that they do not.

We may also notice the equilibrium nature derived from the connecting lines from parents to offspring in Figure 3. The resulting distribution of the quantitative trait in the offspring generation is the same as that in the parental generation, as the crisscross connecting lines balance each other, yielding a stationary state. Limiting attention to changes in



one direction and ignoring those in the other would lead to erroneous conclusions with respect to the population. The genetical model leads to the presence of the crisscross lines on account of gene segregation, while an environmental model would not only require two sets of factors working in opposite directions but also requires that they be of equal magnitude and affect equal numbers of people.

Nongeneticists may at first be amazed at the several very arbitrary assumptions involved in the genetical model. Actually, none of the assumptions are critical to the model; i.e., even if they arc not exactly fulfilled the general pattern shown in Figure 3 will be modified only slightly. The assumptions are made in the interest of arithmetic simplicity, not to create an artificial network of relationships that do not exist in nature. Gene effects may not be additive, and gene frequencies arc seldom equal. Matings are certainly not entirely random with respect to intelligence and education. With all these modifying factors, the essential feature [172] of Figure 3 still remains. The most important single phenomenon of the genetic model is that for any given class of parents, their offspring will be scattered into various classes; conversely, for any given class of offspring, their parents come from various classes. Environmentalists sometimes misunderstand the implications of population genetics, thinking that heredity would imply “like class begets like class.” Probably the opposite is true. Only very strong social and environmental forces can perpetuate an artificial class; heredity does not. From this point of view, social forces are more conservative than hereditary ones.

The Markov property

Of all the genetical properties that I wish to discuss with social scientists the Markov property is probably the most difficult to sell, and yet it is this property that has the most social implications. It is difficult to sell, not because it is intrinsically complicated, but because it is unbelievably simple, so simple that it contradicts the experience of social scientists, as very few, if any, social traits possess the Markov property. At the risk of oversimplification I shall present the case with the following example. Consider the heterozygote (AaBb) son from various types of families:

Father	Value		Son	Value
aabb	0	→	AaBb	2
Aabb	1	→	AaBb	2
AAbb	2	→	AaBb	2
AABb	3	→	AaBb	2
AABB	4	→	AaBb	2

The individual AaBb has a quantitative value of 2 on our scale, regardless of the type of family in which he was born. The value is determined by the genotype of the individual. The only restriction in genetics is that certain types of families cannot produce offspring of a particular genotype. Once the individual is produced, he is no different from other individuals of the same genotype from other families.

Furthermore, the future genetic behaviors of these AaBb individuals are all the same, regardless of the differences among the families from which they come. For example, in the random-mating population considered previously, the children of the AaBb individual will be in the classes 0, 1, 2, 3, 4 with relative frequencies 1, 4, 6, 4, 1, respectively,
whether this AaBb individual is a product of AaBB x AABb [173]
or AABB x aabb, or any other of the many possible parental combinations. If a genotype is referred to as a “state” of an individual, we say that state 2 may be reached from several other states. The property may be summarized in more general language as follows: *The properties of an individual (or an object) depend upon the state in which he finds himself*

and not upon the state from which he is derived. This is known as the Markov property (its simplest kind) in mathematics. Briefly, it says that the properties depend on where you are, not where you are from. It is essentially a property that is independent of the past. A state is a state; it has no memory. A gene is a gene; it has no memory. It is this Markov property with respect to genotypes that enables us to extend our genetic analysis and understanding of the population beyond what has been shown in Figure 3.

Consider the individuals in class 0 in Figure 3. The lines connecting the two generations show that their children will be in classes 0, 1, 2 with relative frequencies 1:2:1. We say that the transitional probabilities from state 0 to states 0, 1, 2 in the next generation are ¼, ½, ¼, respectively. Such transitional probabilities always add up to unity, as they are the conditional probabilities for a given parental state. The transitional probabilities for all the five parental states may be arranged systematically into an array where each row gives the conditional probabilities for each given parental state:

$$\mathcal{T} = \begin{array}{c c} & \textit{State of Children} \\ & \begin{array}{ccccc} 0 & 1 & 2 & 3 & 4 \end{array} \\ \text{State of Father} \begin{array}{c} 0 \\ 1 \\ 2 \\ 3 \\ 4 \end{array} & \left|\begin{array}{ccccc} \frac{1}{4} & \frac{1}{2} & \frac{1}{4} & 0 & 0 \\ \frac{1}{8} & \frac{3}{8} & \frac{3}{8} & \frac{1}{8} & 0 \\ \frac{1}{24} & \frac{6}{24} & \frac{10}{24} & \frac{6}{24} & \frac{1}{24} \\ 0 & \frac{1}{8} & \frac{3}{8} & \frac{3}{8} & \frac{1}{8} \\ 0 & 0 & \frac{1}{4} & \frac{1}{2} & \frac{1}{4} \end{array}\right| \end{array} = \left|\begin{array}{ccccc} 6 & 12 & 6 & 0 & 0 \\ 3 & 9 & 9 & 3 & 0 \\ 1 & 6 & 10 & 6 & 1 \\ 0 & 3 & 9 & 9 & 3 \\ 0 & 0 & 6 & 12 & 6 \end{array}\right| \frac{1}{24}$$

Such an arrangement of conditional probabilities is known as a stochastic matrix or a transitional matrix, designated by $\mathcal{T}$. The matrix is merely an analytical way of presenting the connecting lines between two successive generations. The reason for using the transitional matrix is that the transitional probabilities for two generations, i.e., from grandparents to grandchildren, will be simply given by $\mathcal{T} \times \mathcal{T} = \mathcal{T}^2$, on account of the Markov property of genotypes. Similarly, the transitional probabilities for four generations will be $\mathcal{T} \times \mathcal{T} \times \mathcal{T} \times \mathcal{T} = \mathcal{T}^4$. The events in successive generations thus form a "Markov chain." The results of our calculations are shown in Table 1. The probabilities in each row add up to
unity (except for rounding errors sometimes). It will be [174]
noticed that in the original matrix $\mathcal{T}$ the five rows arc very different. In the matrix $\mathcal{T}^2$ the five rows are still different but not to the same extent as those of $\mathcal{T}$. In the matrix $\mathcal{T}^8$ the five rows become almost the same. Further numerical calculations show that the five rows will indeed become identical as

Table 1. Transitional probabilities from ancestor to descendant

	State of ancestor	State of descendant 0	1	2	3	4
	0	.2500	.5000	.2500	0	0
	1	.1250	.3750	.3750	.1250	0
T	2	.0417	.2500	.4167	.2500	.0417
	3	0	.1250	.3750	.3750	.1250
	4	0	0	.2500	.5000	.2500
	0	.1354	.3750	.3542	.1250	.0104
	1	.0937	.3125	.3750	.1875	.0312
T^2	2	.0590	.2500	.3819	.2500	.0590
	3	.0312	.1875	.3750	.3125	.0937
	4	.0104	.1250	.3542	.3750	.1354
	0	.0784	.2812	.3744	.2187	.0472
	1	.0703	.2656	.3750	.2344	.0547
T^4	2	.0624	.2500	.3752	.2500	.0624
	3	.0547	.2344	.3750	.2656	.0703
	4	.0472	.2187	.3744	.2812	.0784
	0	.0635	.2520	.3750	.2480	.0615
	1	.0630	.2510	.3750	.2490	.0620
T^8	2	.0625	.2500	.3750	.2500	.0625
	3	.0620	.2490	.3750	.2510	.0630
	4	.0615	.2480	.3750	.2520	.0635

the number of generations *(n)* increases, as the theory of stochastic matrices predicts. The limiting value of $\mathcal{T}^n$ as n becomes large is:

$$T^n \longrightarrow \hat{T} = \begin{vmatrix} 1 & 4 & 6 & 4 & 1 \\ 1 & 4 & 6 & 4 & 1 \\ 1 & 4 & 6 & 4 & 1 \\ 1 & 4 & 6 & 4 & 1 \\ 1 & 4 & 6 & 4 & 1 \end{vmatrix} \; 1/16$$

The rows of the $\mathcal{T}^n$ matrix are identical. This means that no [175]
matter what was the given initial state of the original ancestor, his distant descendants will be distributed into the various classes the same way; viz., 1:4:6:4:1, which is the equilibrium distribution of the quantitative trait in the population. Thus, the distant descendants of Jean Bernoulli are distributed into the various classes of mathematical ability exactly the same way as the distant descendants of one whose mathematical ability belongs to class 0. In practice, after only a few generations (Table 1), the transitional matrix becomes indistinguishable from its theoretical limiting value.

Figure 4 is an attempt to illustrate the biological meaning of the mathematical results. Let us first fix our attention on a particular individual, say, some one in class 3, and assume for simplicity that one father has only one son in each generation. If we follow the father-son line of descent from generation to generation, we shall find the line zigzags greatly without any systematic rule. After six or eight generations, the last member of the line may end up almost anywhere along the scale 0-4. And this is true for any individual on whom we happen to fix our attention originally. In each generation the line may take one of several alternatives. The Tn matrix says that no matter which individual of which class we decided to follow, his descendants will be scattered among the classes 0-4 with eventual probabilities 1/16, 4/16, etc. These probabilities are independent of the initial position where we started the follow-up. This if one of the most important and remarkable consequences of the Markov chain events. The mathematical model fits into population genetics better than any other biological subject. In terms of genetic relationships this result means that family members six or eight generations apart are practically unrelated, even though they may retain the same family name.

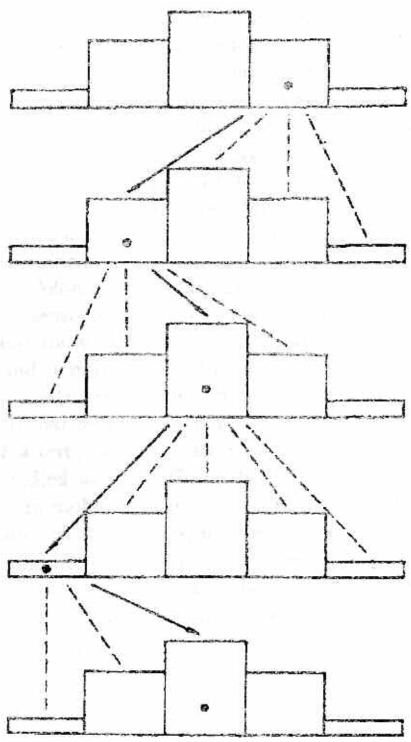


Figure 4. One possible line of descent through four generations

For ease of understanding we have followed from father to son. Actually, the same argument applies for tracing back also. Given an individual in a class (no matter which class), if we trace his father, grandfather, etc. back to six generations, we may find his ancestor almost anywhere along the scale 0-4, with the same probabilities as indicated before.

To summarize, two individuals of the same family but several generations apart are practically uncorrelated in their genetic constitution. Given the genotype of one, we could not estimate the genotype of the other any more accurately than we can for an unrelated random individual. The hereditary forces in shaping up an individual are essentially of an immediate nature and have no long-lasting historical significance. When one tells you that his great-great-grand-uncle came to this country on the Mayflower, a historian or a social scientist may attach some meaning to that fact. A geneticist regards that as "noise," irrelevant to his own worth. It is the social forces (created by man) that tend to protect and maintain a certain class. The genetical forces (created by nature) have no such social prejudices; they obey the laws of probabilities without memory of the past.

The study of racial differences

All quantitative differences, of whatever kind, are based on measurements made under prescribed conditions, frequently under arbitrarily defined conditions. Most familiar examples are the various types of games and competitions in the sports world. Should the boxing ring be lengthened or shortened by one foot in each dimension, the outcome of the fight might be different. Similarly, if the 100-meter track is lengthened to 120 meters or shortened to 80 meters, the outcome of the competition might be quite different. Yet we define and accept the differences among the athletes under such highly artificial conditions, with full knowledge that such observed measurements and differences might be modified as soon as the rules of the game are modified.

Sports records over a long period of time show that [177]
American blacks are better runners and boxers; and this conclusion gains general acceptance without much fuss. Even the most skeptical person will readily admit that the American blacks are at least equally good in running and boxing. Nobody argues that the competition is done under artificial conditions and, therefore, not fair to the blacks or to the whites. That is the game. The running ability is defined by the rules and conditions, although nobody in the real world could or would run 100 meters straight without a turn, and certainly not between two white lines. Swimming is done under similarly artificial conditions, and American blacks are not doing so well in this sport. Purely for the sake of illustration, let us assume that the American black is superior in running and inferior in swimming. These two "tests" measure two different abilities. One's superiority as revealed by one test does not nullify his inferiority in another, or vice versa.

The discussion above by no means applies only to sports abilities. In a sense, the arbitrariness of the rules of sport is true for all types of tests for all types of abilities, including the great variety of tests for "intelligence," whatever that means. In sports one may argue (actually no one does) that the 100-meter dash does not really measure the "running ability" of an individual, as no one runs that way in natural conditions. This is purely a semantic problem. We may easily substitute some other words for running ability if that is the objection. The 100-meter dash measures the ability defined by the specified "tests" (conditions and rules of running), no matter what name we attach to that ability. And the American blacks are very high in that ability as measured by the specified tests. When we are dealing with the ability loosely known as intelligence, to be measured by certain arbitrary tests, however, we tend to lose our objectivity and standard. The ability we are measuring is defined by the tests employed, and it may be called by any name at all.

The current controversy seems to center around two questions: (1) Is intelligence (as defined by tests) determined by heredity? (2) Is there a racial difference in such a test score? Both are matters in basic science, and they must be treated and studied as such. There should be no more room for emotion than in studying the mobility of amoeba. We must face the blunt reality that for matters in basic science there is no other way to make progress except by basic research. As in all other problems in basic science, basic research may be long, slow, tedious, painstaking, expensive, and sometimes even confusing, but it is the only road to progress that we know of. Avoidance of research is certainly no road to progress.

Set it up and knock it down

In our effort to seek the true state of nature (which is unknown), we usually have one or more hypotheses (tentative assumptions) in our mind that we wish to test to determine [178] how true or untrue are the assumptions. Suppose that the truth is $\mathcal{T}$, and our initial hypothesis is H_0. In most cases the chance is remote that $H_0 = \mathcal{T}$. The research procedure is to make our successive hypotheses, (H_1, H_2,…) closer and closer to the truth. In order to be able to accomplish this, the research procedure must be self-policing, self-improving, or self-correcting. When the research procedure possesses these properties, we shall get closer and closer to the truth no matter where we start. That is, even if an initial H_0 is very far from the truth, we shall be able to advance in the right direction toward the truth. The ideal procedure is independent of H_0. This is somewhat analogous to the iterative methods of arriving at a mathematical solution, beginning with an initial trial value.

What is the research procedure that is self-policing and self-correcting? Briefly, it is an endless attempt to *disprove* a hypothesis. First, we set up a hypothesis so that we can initiate the research work. This should then be immediately followed by attempts to show that the hypothesis is untrue so that we may set up a new hypothesis. When the new one is disproved, we shall have a still newer one to take its place and so on. A continuous procedure of this nature will take us closer and closer to the truth even if we started out very wrong. Hence, we see, there is no good or bad hypothesis in science, but there is good or bad scientific procedure. It is the procedure, not the hypothesis, that leads us eventually to the truth. No false hypothesis can survive the self-correcting procedure very long. The continuous effort to disprove a hypothesis will help us not to go too far astray too long.

Thus, it is clear that it serves no purpose in science to set up a hypothesis that can neither be proved nor disproved. Such a hypothesis will remain still as a useless statement; it does not lead us anywhere; it adds no new knowledge; its truth or falsehood will remain unknown; it is incapable of self-improvement. An absolutely necessary feature of a hypothesis is that it is susceptible to being disproved. The scientist will then design discriminating experiments to test its degree of validity and improve the hypothesis to a hopefully truer one.

Some of us, however noble our intentions may be, are so anxious to "prove" a hypothesis that we tend to ignore the procedure of self-policing and ignore evidences unfavorable to the hypothesis. When we do so, the hypothesis ceases to be part of science and becomes ideology or dogma. In order to make progress in science we must be more interested in disproving than in proving. In my brief involvement with the social scientists concerning the hereditary and environmental components of intelligence and the possible racial differences in test scores, my review of the arguments gives me the impression that not sufficient attention has been placed on the self-correcting procedures; and some of the arguments are plainly ideological.

Discussion

After reading this chapter in Illinois a number of questions have been brought to me from various sources. A few of the most frequently raised questions are discussed below. **Q** means question and **D** means discussion.

Q1: You left me dangling as to whether the hypothesis we should disprove is that Negroes are different from Caucasians or that Negroes are the same. It might help if you would state this clearly.

D1: I shall state this clearly. It makes absolutely no difference which hypothesis you choose to attack first, as long as you adopt the self-correcting procedure. As emphasized in the text, it is the procedure (scientific method), not the hypothesis, that leads us eventually to the truth. Flip a coin or simply suit yourself. If I choose one hypothesis, that should not influence your choice at all. Personally, I should like to see various investigators, starting from many different hypotheses, eventually all reach the same conclusion. That would be a beautiful demonstration of the power of the scientific method.

Q2: You give no concrete suggestions as to how we do get around the confounding socioeconomic differences between the Negro and the Caucasian, which in my opinion continue to hinder progress in this field and will do so for the foreseeable future. Perhaps you would like to recognize in print how difficult it may be to test hypotheses in this field.

D2: I did not give concrete suggestions as to how to get around the confounding factors (not limited to socioeconomic differences) between the black and the white, as I am not writing a protocol for a research project. Obviously, there is no one single method that would overcome the effects of all confounding factors. But the situation here is no different from any other social, medical, or epidemiological study which has to face just as many confounding factors in our society. Each investigator has to make his own research design to suit the particular purpose of his project and the particular circumstances under which the project is to take place. The existence of confounding factors is certainly no excuse not to do research in this or any other field. You will encounter confounding factors in all types of research, not only in racial problems. Hypothesis testing is difficult in every field; I recognize it.

Q3: Since all tests are arbitrary devices, then should we attach any meaning to the test scores? Particularly, I mean the IQ tests.

D3: Despite the arbitrary nature of all types of tests, the results or scores do mean something. If they mean nothing else, they at least measure the scoring ability with respect to that particular test. Whether that scoring ability should play a role in society is entirely another problem. The champions in track do have better running ability than the rest of us. Whether we should make them senators or governors is a different question. A popular pitcher of the Pirates got elected to public office in the Pittsburgh area. If the IQ scores really differ between two groups (any two groups, not necessarily blacks and whites), I shall accept it as a fact without any implications. I accept a good pitcher as a good pitcher, but I do not necessarily vote for him in November, in spite of the fact that an administrator also needs a strong arm.

Q4: You are talking about science all the time. What I [180]
want to know is if you were told that the Chinese intelligence is 15 points below the whites, what would you do?

D4: Absolutely nothing! Incidentally there is no "if" about it. I have been told something like that many times since my boyhood, long before the test scores became popular. I seem to hear less and less about that as time goes by. This could be because of my age; I hear less and less about everything else too.

Summary

A systematic and unified explanation is needed for various phenomena observed in a human population or anywhere. Ad hoc explanations are a posteriori and have no predictive value. The properties of a genetical model for quantitative traits have been described and their social significance discussed. It was concluded that social factors act in a more conservative way than hereditary factors in a random-mating population. The genetic hypothesis, environmental hypothesis, or any other hypothesis on human intelligence or any other type of ability must undergo the critical self-improving research procedure. A hypothesis must be susceptible to possible disproof; otherwise it serves no purpose in science. Matters in basic science must be elucidated or resolved by basic research; no ideology can possibly help.

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There are so many reports on the subject of environmental and hereditary components of human intelligence that a listing of a few by an author not working primarily in this field would unavoidably be very biased, if not amounting to total distortion. For this reason the author thought it is best not to list any specific technical work in an article of this nature. However, an extensive bibliography may be found in *Environment, heredity, and intelligence.* Harvard Educational Review, Cambridge, 1969. Those who are interested in the author's writings in general methodology, experimental statistics, population genetics, and its applications in human populations may consult some of the following:

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