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CONTROVERSIES IN INTELLIGENCE: HEREDITY AND ENVIRONMENT

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INDIVIDUAL DIFFERENCES IN ABILITY

Every parent, teacher, and employer, from the dawn of history to the present day, has noticed differences in intelligence among individuals. Although the characteristics of intelligence have long been readily recognized in terms of certain differences among individuals, intelligence itself has been described by many different words—brightness, cleverness, and quickness in learning, in grasping new concepts, and in solving problems. St. Thomas Aquinas characterized intelligence as "the ability to combine and separate," that is to say, the ability to see the differences between things that seem similar and to see similarities between things that seem different. In the terms of modern psychology these are the abilities to discriminate and to generalize. A famous British psychologist, Charles Spearman, described general intelligence, or *g* for short, as "the eduction of relations and correlates."[1] The "eduction of relations" means that when a person is given two "fundaments" (in Spearman's terminology), he can educe an abstract relationship between them. For example, MAN and LEG are related as *whole* to *part*. The "eduction of correlates" means that when a person is given a fundament and a relation, he can educe another appropriate fundament. For example, given COLD and *opposite,* we educe HOT. Thus the essence of *g* is seen as a capacity for perceiving and generating abstract concepts.

Persons are observed to differ, sometimes conspicuously, in the many behavioral manifestations of mental "brightness" or intelligence. Some few persons appear extremely "bright," some appear extremely "dull," and the vast majority fall somewhere between these extremes. But there is a continuous gradation from one extreme to the other, from idiot to genius. A similar gradation of differences is seen in many other characteristics, such as physical stature. Indeed, individual variation (also called individual differences) is a basic fact of biology. Individual variation is, in fact, the essential mechanism, along with natural selection, that has permitted biological evolution to occur.

[1] C. Spearman, *The Abilities of Man* (London: Macmillan & Co., Ltd., 1927).

THE MEASUREMENT OF INTELLIGENCE

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Intelligence is a concept, an abstraction from our observations of individual differences in a certain class of behavior. But such a concept does not become fully amenable to scientific study until it can be given some objective, operational definition. An operational (or scientific) definition of a particular concept or attribute simply specifies the conditions and operations by means of which one can identify, quantify, or measure the attribute in question. Scientifically speaking, the numbers or measurements that we arrive at by means of this operation (or set of operations), plus the operations themselves, are the *meaning* of the concept or attribute. We do not need to think in terms of some excess hidden meaning or Platonic essence behind our scientific operational definition. The measurements yielded by our operations, however, may gain further significance through objectively demonstrated relationships to other observable facts. If measurements are related to nothing else but themselves, they are, of course, trivial. In the parlance of psychological test theory, they are said to be without any validity.

The Binet Scales

The first test of intelligence with practical validity was published by Binet and Simon in 1905.[2] The Ministry of Education in Paris commissioned Binet and Simon to devise a technique for screening out children entering school who would be most likely to experience inordinate difficulty in learning scholastic subjects and who would be most apt to benefit from early placement in special classes before becoming too discouraged by failure in the ordinary classroom. The test devised by Binet and Simon was a scale of mental age, consisting of a series of tasks that were graded in difficulty according to the average age at which children typically could perform the task successfully. The number of tasks "passed" by a child thus placed him on a "mental age" scale comparing his performance with that of the typical child (i.e., the statistical average) at any given age. It was later suggested that the child's *rate* of mental development, or his degree of "brightness" in relation to his age-mates, could be indicated by the ratio of mental age to chronological age (i.e., MA/CA). This ratio (multiplied by 100 to remove the decimal) became known as the Intelligence Quotient or IQ. Lewis M. Terman and his colleagues at Stanford University revised and standardized the Binet scales for use in the United States in 1916. Known as the Stanford-Binet, this individually administered test became the standard operational definition of intelligence and the criterion against which many other tests of intelligence, particularly group-administered tests, were validated. The Stanford-Binet underwent further revisions and restandardization in 1937 and 1960, and it remains today probably the best all-round measure of intelligence. Other well-known tests which yield essentially the same results in terms of IQ, but which have somewhat different content and are constructed along different lines in terms of administration and scoring, are the Wechsler scales (Wechsler Intelligence Scale for Preschool Children, Wechsler Intelligence Scale for Children, and Wechsler Intelligence Scale for Adults).

Educational Correlates

The Stanford-Binet and other closely related individual and group tests of intelligence, having originated as a means of predicting scholastic performance, call upon those aspects of mental ability that are most relevant to the ability to succeed in learning school subjects under the conditions of traditional classroom instruction. For their intended purpose these tests work very well indeed. No other single fact that we can ascertain about a child gives us a better prediction of his future scholastic performance than his IQ. In any one school year the IQ will predict at least half of the variance among children's scholastic achievement, and over the entire

[2] L. J. Cronbach, *Essentials of Psychological Testing*, 3rd ed. (New York: Harper & Row, Publishers, 1970).

course of schooling the IQ will predict 75 to 80 percent of the achievement variance.

Occupational Correlates

Although the IQ had its origins in educational prediction, it is now clear that its significance extends considerably beyond the school setting. It predicts final adult occupational status to almost the same degree that it predicts scholastic performance.[3] When occupations are rank-ordered for average income and for people's judgments of their prestige and desirability, this order is found to be very highly correlated with the average IQ of persons in these occupations. Terman and his associates followed the development of 1,528 so-called gifted children (selected only for having Stanford-Binet IQs above 140) from childhood to adulthood.* It was found that, in general, these high IQ children grew up to be adults who excelled the population of unselected adults by every criterion of a successful and happy life that was examined: a higher level of education completed, more scholastic honors and awards, higher occupational status, higher income, production of more articles, books, patents, and other indices of creativity, more entries in *Who's Who,* lower mortality, better physical and mental health, a lower suicide rate, a lower divorce rate, and brighter children (their average IQ was 133).[4] These results leave little doubt that IQ tests measure characteristics of the individual that are obviously of considerable importance for competing successfully in a technological society such as ours. Indeed, to say that this kind of intelligence is unimportant would be to repudiate civilization as we know it.

General Ability and Specific Factors

Mental ability is not properly thought of in the singular or as a unitary dimension like height. There are numerous abilities, and persons are not uniformly high or low on all of them. For example, the best readers in class are not necessarily the best in arithmetic; and the best in art are not necessarily the best in music. In scholastic activities and in mental tests that involve symbol manipulation, conceptualization, and abstract reasoning, however, there is a fairly high degree of communality. That is, such tests are highly correlated with one another, despite obvious differences in appearance. For example, the ability to solve verbal analogies (e.g., "*Square* is to *circle* as *cube* is to ?.") is highly correlated with the ability to copy designs with colored blocks. Nearly all kinds of tests of mental ability show some positive correlation with one another. In examining over seven thousand correlations among a large number of quite diverse ability tests, Guilford reported finding more than 80 percent significant positive correlations.[5] This means that most ability tests have some common factor. Spearman called this common factor *g* (for general intelligence factor) and invented a mathematical method, known as factor analysis, for determining the proportion of variance due to *g* in any given test. Some tests have been devised to measure the *g* factor and almost nothing else. Raven's *Progressive Matrices* is a good example of such a test; another is Cattell's *Culture-Fair Test of g.* Examination of the items in such tests helps one discern the nature of *g,* the factor common to nearly all tests of mental ability and certainly the predominant factor in all standard intelligence tests. We can best characterize *g* as an ability for abstract reasoning and problem solving. In addition to *g,* a number of other special ability factors are usually found in omnibus-type intelligence tests such as the Stanford-Binet, the Wechsler scales, group tests of scholastic aptitude, and the armed forces qualification tests. The most frequently identified special factors are verbal, numerical, and spatial abilities. The study of the structure of human abilities is much too vast to be more than mentioned here. For comprehensive dis-

[3] Leona E. Tyler, *The Psychology of Human Differences,* 3rd ed. (New York: Appleton-Century-Crofts, 1965).

* See **2.4**, "The Gifted Child."

[4] L. M. Terman and M. Oden, *The Gifted Group at Mid-Life* (Stanford, Calif.: Stanford University Press, 1959).

[5] J. P. Guilford, *The Nature of Human Intelligence* (New York: McGraw-Hill Book Co., 1967).

cussions of this topic the reader must be referred elsewhere.[6]

THE DISTRIBUTION OF INTELLIGENCE

If one makes up a test consisting of items that range in level of difficulty from very easy to very difficult and gives the test to a large number of persons, all of approximately the same age and selected at random from the general population, it will be found that the distribution of raw scores (i.e., the number of correct answers) approximates the so-called normal distribution, with most persons getting scores near the average and fewer and fewer persons having scores approaching the lower and upper extremes. For a variety of theoretical and statistical reasons which need not be discussed here, most standardized tests, especially intelligence tests, are devised in such a way as to yield score distributions that come as close as possible to the "normal curve" in the general population. If it is assumed that intelligence is the result of a large number of factors (e.g., genetic and environmental influences) with independent, additive effects, then, according to the mathematical laws of probability, intelligence should be normally distributed in the population. Figure 1 shows the idealized distribution of IQs, with the percentage of persons within each range of the IQ scale. Actually, however, the distribution of IQs in large, representative samples of the population departs slightly but systematically from the normal curve shown in Figure 1. These departures are shown in Figure 2 in a somewhat exaggerated form for the sake of clarity. It can be seen that there is an excess of very high IQs, and a more marked excess of very low IQs (below 60, and especially below 50). The reason for the excess at the high end remains speculative and may even be an artifact of the scale of measurement, although it could also be predicted from certain principles of quantitative genetics if it were assumed that there is a higher degree of assortative mating for intelligence (i.e., like marrying like) in persons of above average IQ than in persons of below average IQ. The cause of the bulge at the low end of the IQ distribution, however, is not at all speculative, but is known to be the result of biological "accidents"—mutant and recessive genes which completely override the normal determinants of intelligence, chromosomal abnormalities (e.g., Down's syndrome or mongolism), and prenatal, perinatal, and postnatal diseases and injuries of the brain. By far the most of the severe grades of mental deficiency, usually with IQs below 50, are the result of these rare biological misfortunes. On the other hand, the vast majority of persons with IQs above 50 or 60 are a part of the normal distribution

FIGURE 1. The theoretical normal or Gaussian distribution of IQs, showing the expected percentages of the population in each IQ range. Except at the extremes (below 70 and above 130), these percentages are very close to actual population values. (The percentage figures total slightly more than 100 percent because of rounding.)

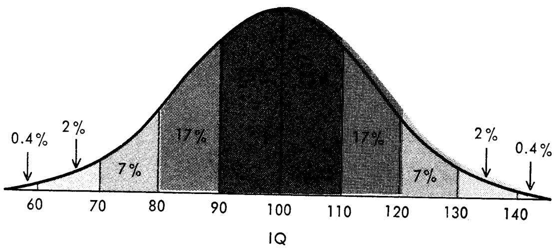
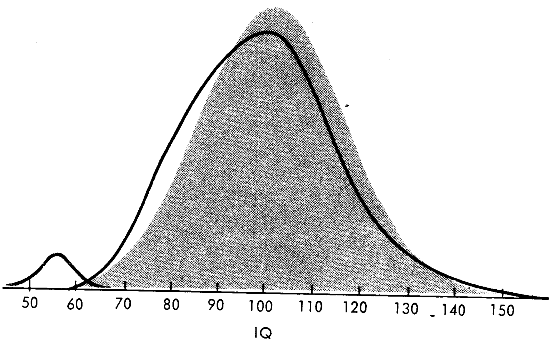


FIGURE 2. Theoretical "normal" distribution of IQs (shaded curve) and the actual distribution in the population (heavy line), with the lower hump exaggerated for explanatory purposes. See text for explanation.



[6] *Ibid.;* J. J. Jenkins and D. G. Patterson, eds., *Studies in Individual Differences* (New York: Appleton-Century-Crofts, 1961); P. E. Vernon, *The Structure of Human Abilities* (New York: John Wiley & Sons, Inc., 1950).

of intelligence.[7] The distinction between *normal* low IQs and *abnormal* low IQs is very analogous to the distribution of height and the distinction between normally short persons and abnormally short persons such as dwarfs and midgets. Most persons with low IQs (i.e., between 60 and 80) are just as normal, biologically speaking, as persons with high IQs. They merely represent the extremes of normal variation in intelligence, just as short persons and tall persons represent the extremes of normal variation in stature.

CAUSES OF INDIVIDUAL DIFFERENCES

The central question with which this article is concerned is: what causes the wide range of normal variation in intelligence? The answer to this simple and obvious question, which has been asked for centuries, is not at all simple or obvious. Understanding the answer entails some difficulties, involving some technical and methodological knowledge of the branch of genetics known as quantitative genetics (also called population genetics). Since mental capacities are ultimately dependent on the structural and biochemical properties of the brain, it should not be surprising that differences in mental ability are partly the result of genetic factors that conform to the same principles that govern the inheritance of physical characteristics. Thus the field of quantitative genetics provides an appropriate methodology for the scientific investigation of the causes of individual differences in intelligence, a methodology originally developed to study the causes of individual variation in many other biological characteristics.[8]

[7] I. Gottesman, "Genetic Aspects of Intelligent Behavior," in *Handbook of Mental Deficiency*, ed. Robert E. L. Faris (New York: McGraw-Hill Book Co., 1963), pp. 253–296.

[8] D. S. Falconer, *An Introduction to Quantitative Genetics* (New York: The Ronald Press Co., 1960); J. L. Fuller and W. R. Thompson, *Behavior Genetics* (New York: John Wiley & Sons, Inc., 1960); Harvard Educational Review, *Environment, Heredity, and Intelligence*, Reprint Series No. 2, 1969; R. C. Roberts, "Some Concepts and Methods in Quantitative Genetics," in *Behavior-Genetic Analysis*, ed. J. Hirsch (New York: McGraw-Hill Book Co., 1967), pp. 214–257.

Before introducing the quantitative-genetic analysis of individual differences, it may be well to say a few words about three other theoretical approaches to this problem that have had some popularity at one time or another. They are generally characterized by a lack of any clear formulation and of any sound methodology that could rigorously test them, and they have been propounded in complete disregard of the theory, methods, and empirical findings of quantitative-genetic research.

The "Predetermined" or "Fixed Intelligence" Theory

Although the "fixed intelligence" theory had some currency half a century ago, it is not espoused today by any known psychologists or geneticists. Today it remains at most a "straw man" that is all too easily attacked by proponents of other theoretical positions. The "fixed intelligence" notion holds that *all* individual variation in IQ (except errors of measurement) is determined once and for all at the moment of conception, completely spelled out in the genetic code, only having to unfold with complete predictability throughout the course of the individual's development, regardless of the environmental factors that impinge. According to this view, once the genetic dice have been tossed and conception has taken place, the individual's intellectual fate is sealed. This view is completely contradicted by numerous lines of evidence.

The Environmentalist Theory

The environmentalist view takes just the opposite stand. Genetic differences are seen either as non-existent or as so small as to be a negligible factor in the development of intelligence. Environmental and cultural influences are claimed to be the overriding determinants of intelligence. Individual differences in IQ are attributed to inequalities in environmental, cultural, and educational opportunities. Like the "fixed intelligence" theory, the extreme environmentalist theory is unsupported by the evidence.

The Interactionist Theory

This view was intended to replace naive environmentalism. It is not a clearly formulated theory and in its predictions and claims it is practically indistinguishable from the environmentalist theory described above. The interactionist theory holds that, although there are significant genetic differences at the time of conception, the organism's development involves such complex interactions with the environment that the genetic blueprint, so to speak, becomes completely hidden or obscured beneath the impenetrable overlay of environmental influences. This view seems to argue, therefore, that the relative influences of genetic and environmental factors cannot be disentangled. In short, the question of the relative importance of heredity and environment in the development of a characteristic is seen as fundamentally unanswerable.

It is true that no organism comes into existence without a genetic basis or develops without an environment. To say that heredity and environment are equally important, therefore, is only tantamount to stating that the organism exists. The interactionist position essentially says no more than this. What we actually wish to know, however, is what proportion of the variation in a particular trait among individuals is attributable to their genetic differences and what proportion is attributable to differences in their environmental circumstances. For the answer to this question, we must turn to the methods of quantitative-genetic analysis.

THE QUANTITATIVE-GENETIC APPROACH

The question that quantitative-genetic methods attempt to answer is, in technical terms: what proportion of the variance of phenotypes is attributable to the variance of genotypes? To understand this question, we must keep in mind clear definitions of its terms.

A *phenotype* is an actual, observable, or measurable characteristic or attribute of the organism. It is, for example, a person's eye color, or his height, or his weight, or his IQ. It is not his intelligence in some abstract or idealized sense, but only the measurement, test score, or IQ as obtained by some objectively defined set of operations. In short, phenotypes are the basic observations—the raw data—with which we begin our analysis.

A *genotype* is a hypothetical construct representing the genetic factors (i.e., a gene or a combination of many genes) that form the biological basis of the phenotype and condition its development from conception on. It is, so to speak, the genetic blueprint for the development of the phenotypic trait. The genes are complex protein molecules that condition the development of the physical substrate of behavior—the brain and nervous system and all the other physiological and biochemical systems that interact with them. The individual's genotype is formed at the moment of conception by the uniting of the maternal and paternal sex cells (ovum and sperm), each carrying its complement of twenty-three chromosomes—a random selection of half of each parent's forty-six chromosomes. Each chromosome carries some undetermined thousands or tens of thousands of genes.[9]

Variance is a technical term with an exact meaning in statistics. It is a quantitative expression of the amount of individual differences (or "variability" or "dispersion") among a number of measurements. If we subtract from each measurement the mean (arithmetic average) of all the measurements, then square each difference, sum these squared differences, and divide the sum by the total number of measurements, we obtain the variance of the set of measurements. The square root of the variance is known as the *standard deviation* of the distribution. The standard deviation of Stanford-Binet IQs in the normative population is 16 IQ points and their variance consequently is $(16)^2$ or 256. A complex mathematical technique known as the *analysis of variance,* invented by the British geneticist and statistician Sir Ronald Fisher, permits

[9] G. E. McClearn, "The Inheritance of Behavior," in *Psychology in the Making,* ed. L. Postman (New York: Alfred A. Knopf, Inc., 1962), pp. 144–252.

one to analyze the variance of a characteristic in the population into a number of additive components, each component representing that part of the total variance which is attributable to some particular identifiable source. We can take a group of adults—for example, fifty men and fifty women—and measure the height of each. We can then calculate the total variance of heights in this group. By analysis of variance we can calculate how much of the variance is due to the difference between the sexes and how much is due to differences among individuals within each sex. Similarly, if we have a large number of groups of siblings, analysis of variance can tell us how much of the total variance is attributable to differences among families and how much is attributable to differences within families.

The familiar correlation coefficient can be derived from the analysis of variance. Correlations between persons (e.g., siblings, or twins, or parents and children) tell us what proportion of the total variance these persons share. It is by analyzing the correlations among groups differing in kinship (i.e., the degree of genetic relationship) that quantitative genetics can answer the question: what proportion of variance in phenotypes is attributable to genetic differences and what proportion is attributable to nongenetic (i.e., environmental) factors?

The Concept of Heritability

The heritability (H) of a characteristic tells us the proportion of variance in phenotypes (V_P) in the population that is attributable to variance in genotypes (V_G). $V_P - V_G = V_E$, the variance due to nongenetic or environmental factors, which include prenatal biological factors as well as postnatal biological factors (nutrition, disease, etc.) and psychological factors (home influences, opportunities for learning, etc.).[10] Thus, $V_P = V_G + V_E$. And heritability or $H = \frac{V_G}{V_P}$. V_G in the above formula can be further analyzed into several genetic components (additive genic effects, dominance deviation, an assortative-mating component, and epistasis or the interaction among genes), and V_E can also be further anlayzed. Explication of these subcomponents of V_G and V_E is beyond the scope of this article, and the reader is referred elsewhere for more detailed information.[11]

H for a given trait is not a constant or fixed value, like the ratio of the circumference to the diameter of a circle. It is not an absolute value or a Platonic essence. H is a population statistic, that is, an empirical estimate of a population characteristic based on a sample from a particular population. Like every statistic, it is subject to sampling error. It describes the heritability of a characteristic in a given population, as measured by a particular method, at a particular time. H reflects the range of genetic and environmental variation in the particular population on which it is based. H does not tell us what the heritability of the trait would be in other populations or under quite different conditions.

H is calculated from the correlations between sets of individuals of different degrees of kinship. The conceptually simplest example is of identical twins reared apart in uncorrelated environments. Identical twins have the same complement of genes and therefore any difference between them is due to nongenetic factors. The correlation between identical twins reared apart tells us the proportion of variance they share, and if they are reared apart in uncorrelated environments, the only source of variance they will have in common is genetic variance. The correlation between them is therefore an estimate of the proportion of genetic variance. The correlation between identical twins reared apart, insofar as they are reared in uncorrelated environments, is equal to the heritability, H. The proportion of environmental variance is, therefore, $1 - H = E$. More complex formulas make it possible to estimate H and E from comparisons of the correlations between other kin-

[10] J. McV. Hunt, *Intelligence and Experience* (New York: The Ronald Press Co., 1961); A. R. Jensen, "Social Class and Verbal Learning," in *Social Class, Race, and Psychological Development*, ed. M. Deutsch, I. Katz, and A. R. Jensen (New York: Holt, Rinehart & Winston, Inc., 1968), pp. 115–174.

[11] C. Burt, "The Inheritance of Mental Ability," *American Psychologist*, 13 (1958), 1–15; Fuller and Thompson, *Behavior Genetics;* Harvard Educational Review, *Environment, Heredity, and Intelligence;* Roberts, "Some Concepts and Methods in Quantitative Genetics."

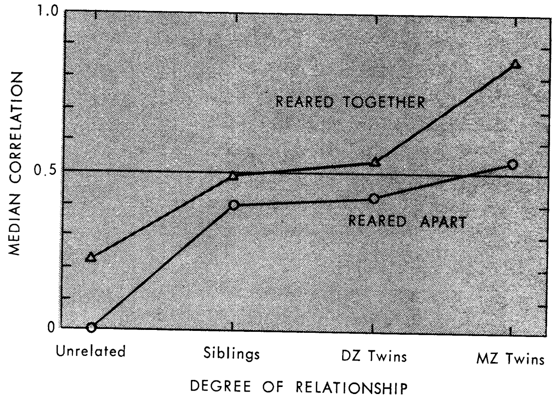


FIGURE 3. Median values of all correlations reported in the literature up to 1963 for the indicated kinships. (After Erlenmeyer-Kimling & Jarvik, 1963.) Note consistency of difference in correlations for relatives reared together and reared apart.

ships, such as fraternal twins, siblings, and parent-child (all of whom have only half their genes in common), half-siblings, cousins, and unrelated children reared together.[12] Since unrelated children reared together have nothing in common genetically, the correlation between them is attributable to their common environment and is therefore an estimate of E. And $1 - E = H$. The average value in several studies of the correlation between twins reared apart is .75, which represents the proportion of genetic variance; the average value of the correlation between unrelated children reared together is .24, which represents the proportion of environmental variance. These estimates of H and E theoretically should add up to unity, and, in fact, they come very close to it.[13] Figure 3 shows the average values of correlations for various kinships when reared together and apart. Unrelated children have no genes in common, siblings and fraternal (dizygotic) twins have half their genes in common, and identical (monozygotic) twins have all their genes in common. The graphic presentation highlights the relatively constant effect of conditions of rearing (together versus apart) on the magnitude of the correlations. Table 1 summarizes the median values of all the kinship correlations for intelligence reported in the literature. The correlations are based on a wide variety of mental tests, administered under a variety of conditions by numerous investigators with contrasting views of the importance of heredity. Table 1 also shows the correlations predicted from strictly genetic models, that is, the genetically expected correlations if there were no environmental variance at all.

Formulas derived in quantitative genetics permit an overall estimate of H from the correlations in Table 1. Since these correlations are based largely on samples from European and North American Caucasian populations, the value of H that they yield is probably the best average estimate available for these populations. The overall value of H derived from Table 1 is .77. If we correct this value for attenuation (i.e., error measurement due to test unreliability, assuming an average test reliability of .95), the value of H becomes .81. Thus it can be said that in European and North American Caucasian populations genetic factors account for about 80 percent of the variance in intelligence; about 20 percent is attributable to all other sources of variance.

The square root of the heritability ($\sqrt{H}$) tells us the correlation between phenotypes and genotypes, that is, the correlation between individuals' IQs and their genotypes for intelligence. This correlation is close to .90. This can only mean that intelligence tests do indeed reflect individuals' innate endowment for intelligence. If they did not, it would be impossible to obtain the values of H that are in fact obtained in numerous studies.

Figures 4 and 5 are intended to help the reader visualize the effect on the normal distribution of IQs of removing the variance due to heredity (Fig. 4), and of removing the variance due to environment (Fig. 5). Figure 4 shows that the range of phenotypes for a single genotype can be quite great even in the

[12] A. R. Jensen, "Estimation of the Limits of Heritability of Traits by Comparison of Monozygotic and Dizygotic Twins." *Proceedings of the National Academy of Science*, 58 (1967), 149–157.

[13] C. Burt, "The Genetic Determination of Differences in Intelligence: A Study of Monozygotic Twins Reared Together and Apart," *British Journal of Psychology*, 57 (1966), 137–153; H. H. Newman, F. N. Freeman, and K. J. Holzinger, *Twins: A Study of Heredity and Environment* (Chicago: The University of Chicago Press, 1937); J. Shields, *Monozygotic Twins Brought Up Apart and Brought Up Together* (London: Oxford University Press, 1962).

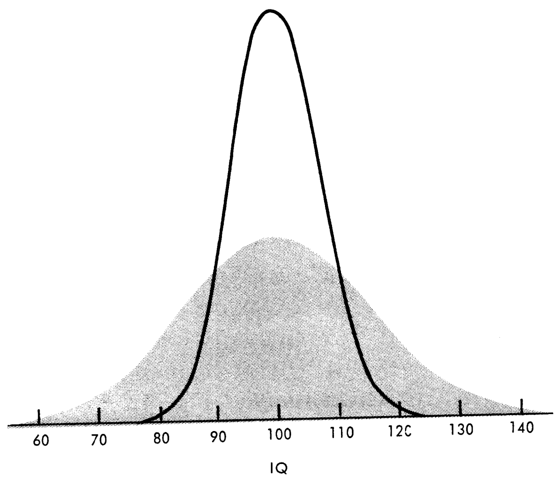
TABLE 1 Correlations for Intellectual Ability: Obtained and Theoretical Values.

CORRELATIONS BETWEEN	NUMBER OF STUDIES	OBTAINED MEDIAN r*	THEORETICAL VALUE†	THEORETICAL VALUE‡
UNRELATED PERSONS				
Children reared apart	4	−.01	.00	.00
Foster parent and child	3	+.20	.00	.00
Children reared together	5	+.24	.00	.00
COLLATERALS				
Second cousins	1	+.16	+.14	+.063
First cousins	3	+.26	+.18	+.125
Uncle (or aunt) and nephew (or niece)	1	+.34	+.31	+.25
Siblings, reared apart	33	+.47	+.52	+.50
Siblings, reared together	36	+.55	+.52	+.50
Dizygotic twins, different sex	9	+.49	+.50	+.50
Dizygotic twins, same sex	11	+.56	+.54	+.50
Monozygotic twins, reared apart	4	+.75	+1.00	+1.00
Monozygotic twins, reared together	14	+.87	+1.00	+1.00
DIRECT LINE				
Grandparent and grandchild	3	+.27	+.31	+.25
Parent (as adult) and child	13	+.50	+.49	+.50
Parent (as child) and child	1	+.56	+.49	+.50

* Correlations not corrected for attenuation (unreliability).
† Assuming assortative mating and partial dominance.
‡ Assuming random mating and only additive genes, i.e., the simplest possible polygenic model.

range of environments sampled in European and North American Caucasian populations. Figure 5 shows that the range of phenotypic variation would still be great even if all nongenetic factors were completely equalized. Another way of expressing the relative effects of genetic and environmental factors on IQ is in terms of the average absolute difference between persons paired at random in the population. The average difference between persons at present is 18 IQ points. If all persons had identical heredity, but environmental differences remained as they are, the average difference would be 8 IQ points. If, on the other hand, all persons had identical environments, but genetic differences remained as they are, the average absolute difference between persons would be 16 IQ points.

FIGURE 4. Comparison of what the distribution of IQs theoretically would be if all genotypes were identical (for IQ 100) in an "average" environment (assuming a normal distribution of environmental advantages) and all variance were due only to nongenetic (environmental) factors (heavy line). Under these conditions the heritability (*H*) of IQs would be zero, instead of .80 as in the present population. The shaded curve represents the normal distribution of IQs in the present population.



There are many other lines of evidence besides kinship studies that indicate the predominant role of genetic factors in intelligence differences.[14] Children reared from birth in the relatively uniform environment of an orphanage show about the same variability in IQ as children reared in their own homes. The IQs of adopted children correlate more highly with the IQs of their true parents than of their adoptive parents.[15] Genetic theory

14 H. E. Jones, "The Environment and Mental Development," in *Manual of Child Psychology,* ed. L. Carmichael, 2nd ed. (New York: John Wiley & Sons, Inc., 1954), pp. 631–696.

15 M. P. Honzik, "Developmental Studies of Parent-Child Resemblance in Intelligence," *Child Development,* 28 (1957), 215–228.

predicts a lower average IQ for the offspring of consanguineous matings, and studies of the children from cousin marriages show them to have an appreciably lower average IQ (by about 8 points) than children of unrelated parents matched with the cousin marriages for IQ, age, education, and socioeconomic status. This cannot be explained in terms of environment but is entirely predictable from genetic principles.[16]

The overall consistency of major studies of the inheritance of intelligence clearly leads to the conclusion that genetic factors are of predominant importance as a cause of individual differences in intelligence in our present society. The results indicate that current IQ tests do, in fact, reflect innate intellectual potential (to a degree indicated by *H*), and that biological inheritance is some three to four times as important as environmental factors in determining IQ variance. This is not to say, however, that as yet undiscovered biological, chemical, or psychological forms of intervention in the genetic or developmental processes could not diminish the relative importance of heredity as a factor in intellectual differences.

Special Abilities

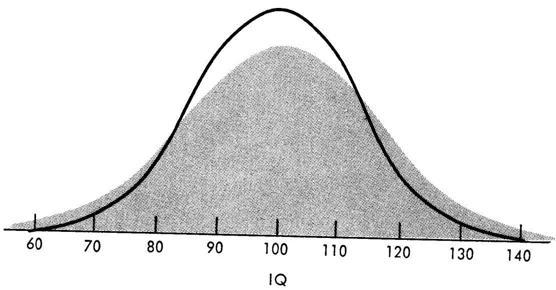
So far we have discussed the heritability of general intelligence. Studies of special abilities, independent of *g*, such as verbal, space, number, word fluency, memory, and perceptual speed have found heritabilities mostly ranging from .50 to .70, which is slightly lower than the heritability of omnibus measures of general intelligence.

Scholastic Performance

Tests of scholastic achievement, school grades, and academic rank in graduating class all show much lower heritability than IQ. The major studies of the heritability of scholastic achievement yield an average *H* value of .40, which is only half as high as for IQ. This means that environmental factors, mainly

[16] Harvard Educational Review, *Environment, Heredity, and Intelligence.*

FIGURE 5. The theoretical distribution of IQs if all variance due to environmental factors were eliminated (with everyone having an "average" environment) and all the remaining variance were due only to genetic factors (heavy line). Under these conditions the heritability (*H*) of IQs would be 1.00. The shaded curve represents the normal distribution of IQs in the present population, in which *H* = .80.



family influences—standards, values, and attitudes concerning education—play a much more important role in producing differences in scholastic performance than in intellectual ability per se. The importance of these family influences is attested to by the fact that siblings reared in the same family differ much less in scholastic performance than in IQ. Figure 6 shows kinship correlations and average differences for scholastic achievement as compared with traits having much higher heritability—height and intelligence.

EDUCATIONAL IMPLICATIONS

Individual differences in measured intelligence are reflected in the child's performance in school in a variety of ways: in the age at which he reaches optimal readiness for beginning classroom instruction in certain school subjects (especially reading and arithmetic), in the ease and speed with which he learns scholastic subjects under ordinary conditions of instruction, in his generalization and transfer of learning from one lesson to the next and from one subject to another, and in his ability to apply principles learned in one context to somewhat novel situations. Given other necessary conditions of learning, such as good mo-

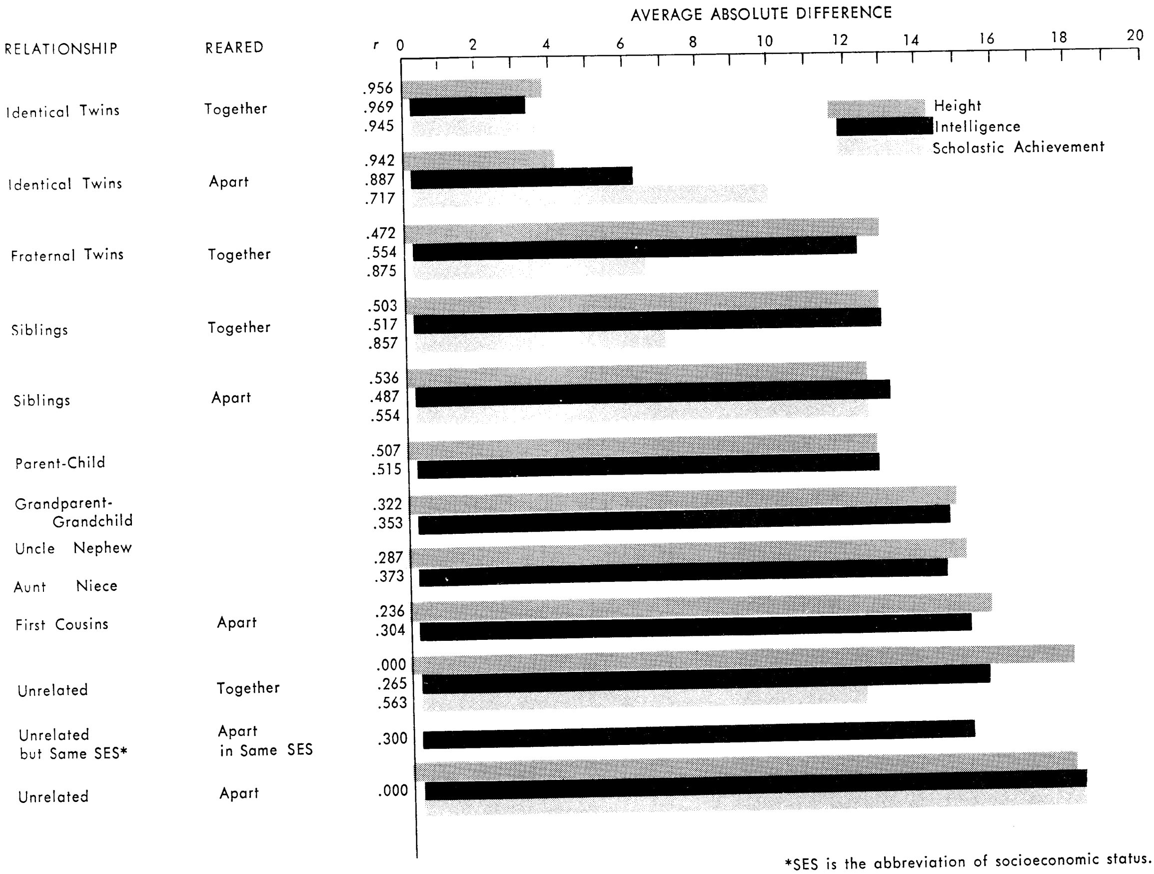


FIGURE 6. Correlations, *r* (corrected for attenuation, i.e., error of measurement) between persons with different degrees of kinship and reared together or apart. The average absolute difference (corrected for error of measurement) between pairs of individuals is based on the same scale for height, intelligence, and scholastic achievement, with a standard deviation (SD) of 16, the SD of Stanford-Binet IQs in the normative population (Jensen, "Social Class, Race, and Genetics").

tivation and good study habits, differences in intelligence are also reflected not only in the rate of attainment but also in the levels of mastery and complexity that are generally reached. The learning of addition and subtraction, for example, will not reflect IQ differences to as great an extent as the more complex operations of multiplication and long division, which in turn are not as discriminating as the still more complex and abstract concepts of algebra, geometry, and calculus. Similarly, penmanship and spelling ability are much less differentiated along the lines of IQ than is ability in written composition.

Despite real differences in ability, however, a diversity of appropriate instructional programs and flexibility in the age grading of school subjects can make it possible for the vast majority of children to attain at least the basic scholastic skills during their years in school.

Since mental abilities are distributed over a wide range and are reflected in differences in educability, and since most of this variability is related to both genetic and environmental factors that are not directly under the school's control, it seems a reasonable conclusion that schools and society must provide a range and diversity of educational methods, programs, and goals, and of occupational opportunities, just as wide as the range of human abilities. Equality of educational opportunity accordingly is not to be interpreted as uniformity of instructional facilities and techniques for all children. Diversity rather than uniformity of approaches holds greater promise for making education rewarding for children over the full range of abilities. The reality of individual differences should not mean educational rewards for some children and frustration and defeat for others. If the ideal of universal education is to be successfully pursued, the extent to which all children can be beneficiaries of the educational system will depend in large part on the proper recognition of individual differences.

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