10/6

10/6 nett
e/i

TWINS AND ORPHANS

TWINS AND ORPHANS

THE INHERITANCE OF INTELLIGENCE

A Thesis Submitted in Conformity with the Requirements for the Degree of Doctor of Philosophy in the University of Toronto

BY

ALEX. H. WINGFIELD

B.A.SC., PH.D.

1928

LONDON & TORONTO

J. M. DENT & SONS, LTD.

5 949 069

29577

PRINTED IN GREAT BRITAIN

ACKNOWLEDGMENTS

WITHOUT the willing co-operation of a number of people this study would have been impossible. I wish to thank the principals of the public schools of Toronto and Hamilton who kindly allowed the twins in their schools to be given the various tests. The children who served as subjects for the study are deserving of my gratitude for the diligent manner with which they applied themselves during the tedious and trying period of testing. But most of all I wish to acknowledge my great indebtedness to Dr. Peter Sandiford of the Ontario College of Education, who inspired this study and under whose constructive guidance and criticism it has been completed.

I also thank the authors whose works appear in the Bibliography, and from which I have freely drawn.

ALEX. H. WINGFIELD.

CONTENTS

CHAPTER X

APPENDIX A

APPENDIX B

APPENDIX C

LIST OF TABLES

LIST OF DIAGRAMS

TWINS AND ORPHANS

CHAPTER I

GENERAL NATURE OF THE PROBLEM

John Stuart Mill remarked that "the greatest thing in the world is man, and the greatest thing in man is mind." Surely the most difficult thing on earth is the accurate measurement of the potentialities of that mysterious entity which people so glibly speak of as "the mind." For scientific purposes this term "mind" is an unusable concept. We shall, therefore, substitute for it the chief attribute of the mind, intelligence, or the capacity for intelligent behaviour. This latter is what our "intelligence tests" are presumed to measure.

Psychologists hold varying opinions as to the meaning of the term "intelligence." A few of the better definitions are given below:

(*a*) Binet. "It seems to us that in intelligence there is a fundamental faculty, the alteration or lack of which is of the utmost importance for practical life. This faculty is judgment, otherwise good sense, the faculty of adapting oneself to circumstances. To judge well, to comprehend well, to reason well, these are the essential activities of intelligence."[1]

[1] Kite's translation of Binet's *The Development of Intelligence in Children*.

Later[1] he describes the features of intelligence as "(1) the tendency to take and maintain a definite end or direction; (2) the capacity to make adaptations in pursuance of the directing end to be obtained, which guides the subject even unconsciously; and (3) the power of self-criticism whereby the person can judge of what has been done with reference to the end and the standard."

(*b*) Meumann. "From the psychological view-point, it is the capacity for independent, productive thought, whereby new mental products may be created out of the data supplied by the senses and memory. From the practical point of view, it is the intensity of the whole mental life, which functions in the correction of mistakes, the overcoming of difficulties, and in adaptations to environmental conditions."

(*c*) Burt suggests that "it is one feature or function of attentive consciousness which forms the basis of intelligence, namely, the power of readjustment to relatively novel situations by organising new psycho-physical co-ordinates. Of all the tests proposed, those involving higher mental processes, such as reasoning, vary most closely with intelligence."

(*d*) Terman. "An individual is intelligent in proportion as he is able to carry on abstract thinking."

(*e*) Stern. "Intelligence is a general capacity of an individual to adjust his thinking to new requirements; it is general mental adaptability to new problems and conditions of life."

(*f*) Thorndike. "We may then define intellect in general as the power of good responses from the point of view of truth or fact. . . . Intelligence is the power of making good responses to abstract qualities or relations."

(*g*) Spearman and Hart agree that "there is a mental

[1] *L'Année Psychologique*, 1909: "L'Intelligence des Imbéciles."

activity which may be designated as intelligence. It is a common central factor or central tendency, not lending itself to exact definition, but which participates in a greater or less degree in special mental activities of all sorts."

Recently Spearman has rejected the term "intelligence," since in its ordinary, present-day usage it does not possess any definite meaning. He now states that "the main feature of cognitive operation always consists in educing relations and educing correlates."

Certain psychologists try to find out what intelligence is as a bodily process, especially in terms of the neural activity of the central nervous system. Thus Sandiford says: "Intelligence is a function of the central nervous system. If a person has a nervous system which integrates easily and tenaciously, he is likely to be bright and intelligent. If, on the other hand, his nervous system forms neuronic paths with difficulty, if associations are hard to form and are soon lost, he is certain to be dull and stupid. Specific training is still needed to form the associations (neuronic paths), but the learning is easy if there is good nervous material to work upon."

After perusing all these definitions one may well acquiesce with Ballard [1] when he says: "While the teacher tried to cultivate intelligence, and the psychologists tried to measure intelligence, nobody seemed to know precisely what intelligence was."

Everyone agrees that it is impossible to measure pure native intelligence, the term "native" being used in the

[1] Ballard, P. B., *Mental Tests*, 1920, p. 23.

sense of not being directly affected by specific training. But what can be measured are the responses which an individual makes when confronted with a variety of situations requiring intelligent behaviour for successful adaptation to the situations thus presented. And in our stock intelligence tests a multitude of varying situations are presented, each of such a nature that an individual could respond successfully, providing his mind had grown normally in a normal environment. It is assumed that if a group of individuals be given similar educational opportunities, then the differences found among the group will be due to differences in native intelligence.

The makers of intelligence tests did not sit down and draw up a definition of intelligence and then proceed to make a series of tests which would measure what they had defined. Rather they proceeded as the physicists did when they devised instruments for measuring electricity before they were able to give a satisfactory definition of what they were measuring. In a similar manner the intelligence test makers made their tests first and then gave the name of " intelligence " to that which the tests measured.

It is generally conceded that the better intelligence tests do succeed in measuring some mental function. This function, which the test-makers call " intelligence," has certain well-defined qualities: (*a*) It appears to increase with a child's growth up to the middle of the " teens " and then to stop; (*b*) up to sixteen or thereabouts it bears a constant ratio to the child's chronological age; (*c*) it is independent of *special* schooling or *special* training; and (*d*) it correlates highly with success, both in school and in later life.

Intelligence tests really measure native ability plus acquired knowledge and interest and habituation, the opportunities to acquire the last three factors being approximately standardised for all children living in any given generation in a given civilised community. But since intelligence-test results are closely related to past success in school and enable us to predict such success in the future, we can perhaps best define that which they measure as "the general mental ability necessary for success in school work."

Having given some insight into the concepts and general principles underlying the efforts to measure intelligence, we shall now consider some of the more important implications involved in the solution of the problem of the inheritance of intelligence.

To some it may not appear essential to learn which of our characteristics are hereditary and which are environmental. But by many serious thinkers such knowledge is regarded as of paramount importance. The following questions will have much light shed on them when we know just how much of what we call intelligence is inherited. (1) How great is the resemblance in mental traits among children of the same parents or ancestry? (2) To what extent are abilities in school work inherited? (3) To what extent are the wide ranges of abilities due to native equipment or to opportunity and environment? (4) What part of the future adult is really determined by the school as an agency of his environment and what part is beyond the control of the school? (5) What are the limitations of education, if any, in the elevation of the races; in other words, can racial differences be educated away? (6) Does education affect only the generation to which it is given, and if so, why? (7) Can the ideal system of education create or even increase intelligence, or can it only give to child or man the material for his intelligence to play upon?

Some of our most violent racial antipathies are based entirely on environmental characteristics, *e.g.* language. But table manners, fashions in foods and dress, methods of living, attitudes towards music and art, behaviour in the relation of the sexes, etc., must be studied from the double standpoint of heredity and environment, if a scientific evaluation is to be made of them.

There are two ideal methods of studying the effect of inheritance. First, place children of different inheritance in an identical environment from birth up to a given point in life, and measure the amount of the similarities and differences. Secondly, place children of identical inheritance in a dissimilar environment up to a given point in life and measure the amount of the similarities and differences.

The above conditions, of course, cannot possibly be realised. The nearest approach to either of them is reached in (1) a study of the two types of twins, fraternal and identical, and (2) in a study of orphans, reared for a certain proportion of their lives in a fairly constant environment. As we shall show in the following chapter, identical twins are the only people in the world having identical inheritances. Those persons known to us as fraternal twins may approach this standard, but their inheritances are never identical. Since the whole problem of intelligence is interwoven with that of heredity and environment, we shall now consider the cellular basis of heredity and the effect of environment upon the inherited bodily structure.

CHAPTER II

HEREDITY AND ENVIRONMENT

EVERY individual is the resultant of the action of the stimuli from his environment upon his inherited, or native, equipment. Native equipment we shall understand to be synonymous with *heredity*, which is perhaps best defined as the complete potentialities of the individual at the time of the union of the gametes which produce the zygote (or fertilised egg). In a strict sense this is the individual's *inheritance*, but we shall use the term heredity for it, since this is what is commonly understood by the term. Environment is the sum total of all the stimuli (including food) which act on the individual. At most, these stimuli can but modify the original hereditary material; they cannot add to it in any way.

Since an individual is the *product* of both heredity and environment, it is well-nigh impossible to evaluate the effect each has in moulding him. From the time of the ancient Greeks to the beginning of this century, innumerable attempts have been made to solve the problem. However, the conclusions that had been reached were very doubtful, since they were based entirely on subjective judgment. Opinions varied from that of Aristotle,[1]

[1] Aristotle, *Ethics*, Book X, Chap. IX.

who maintained that "the gift of Nature is not in our power, but is bestowed through some divine disposition upon those who are truly fortunate," to Locke and Helvetius, who attributed such differences as are found among men merely to differences in training. They compared the mind to a *tabula rasa*, on which one might write anything at will.

To the insight and ingenuity of Sir Francis Galton we owe the first crucial attempt to solve the problem scientifically, and to lift it out of the chaos into which it had

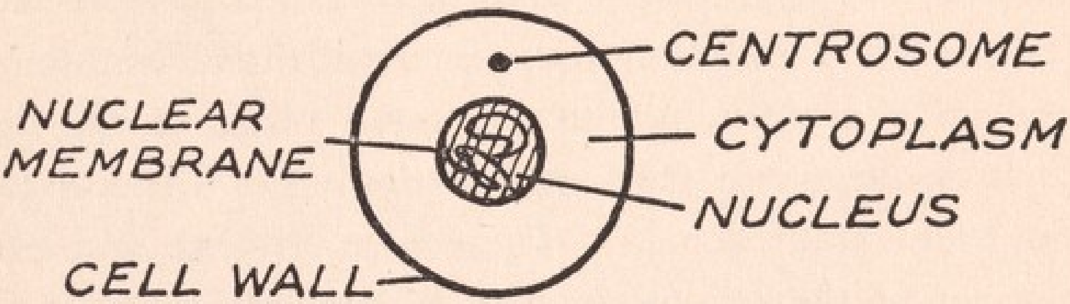

FIG. 1.—Diagram of a Cell.

fallen. He was the first to draw attention to the fact that there are two kinds of twins: identical and ordinary or fraternal twins. Sometimes we meet two people so strikingly alike that it is impossible to distinguish them apart. These are identical twins, and, as we shall show later, they are much more closely related than are the other type, known as fraternal twins.

In order to understand the connection between twins and heredity, we must first study the cellular mechanism by which heredity works. A typical cell about to divide is shown in Fig. 1.

In every cell there are two well-marked regions, the central nucleus and the surrounding cytoplasm. The nucleus is bounded by a nuclear membrane and within it are a number of substances. Under a powerful microscope threads of a faintly-staining material, *linin*, are seen forming a network throughout the nucleus. But embedded in the strands of this network are densely stainable complex granules called *chromatin*.

During the process of cell division, as shown in Fig. 2, the thread-like material in the nucleus begins to flow together, forming a deeply-stained thread which later breaks up into a definite number of pieces of the chromatin material. These pieces are then called *chromosomes*. The nuclear membrane disappears and the chromosomes take up a position in the equatorial plane of the cell. Each chromosome then splits lengthwise, forming two daughter chromosomes. These next diverge and each member of the pair withdraws to opposite poles of the cell. Thus each end or pole of the cell is now occupied by a set of chromosomes which are duplicates of each other, since the material of each individual chromosome has its exact counterpart in the other. When the chromosomes have gathered into the two polar areas there is an internal fusion within each group, and two new nuclei, each similar to the original one, are formed. Simultaneously with all this, a division of the cell body is going on which, when finished, results in the formation of two complete new cells. In this manner all the cells of an individual are formed, each being a replica, as far as the chromosomes are concerned, of the original cell, the fertilised ovum.

One may wonder how the chromatin in the daughter cell can become equal again to the amount originally in the parent cell, as it is only half of it when the daughter

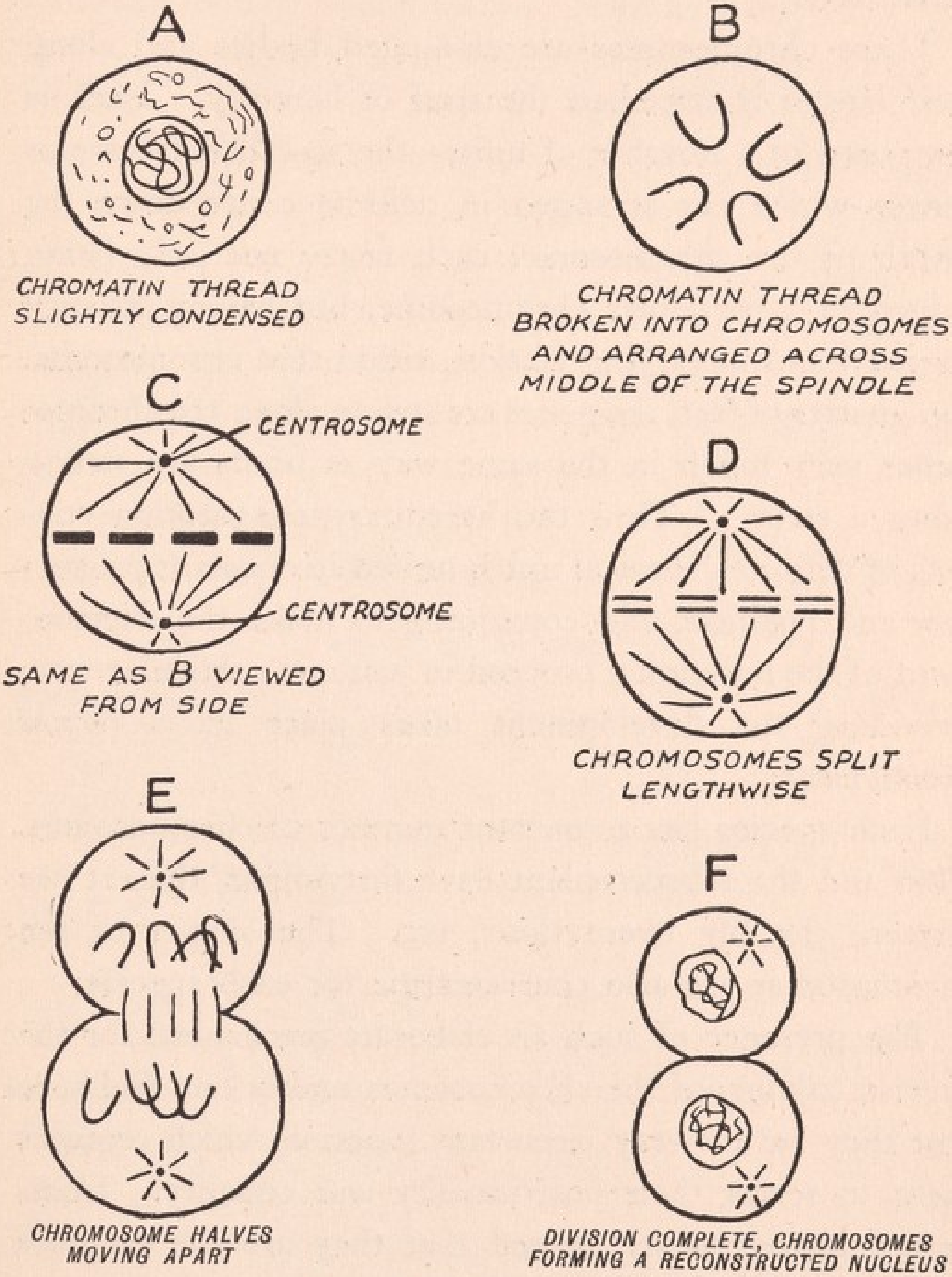

FIG. 2.—Cell Division of Ascaris.

cell separates. Since, however, all living matter can, if given suitable food, convert this food into living matter of its own kind, we are able to understand how the new cell, and the chromatin within, attain to the bulk of the parent cell.

These chromosomes are elongated bodies and along their length is stretched the stuff of heredity. Each is composed of a number of units—the so-called factors or genes—which are arranged in definite order down the length of the chromosome, each factor not only being lodged in a particular chromosome, but having its own assigned and unvarying station within that chromosome. As a matter of fact, the genes are strung along the chromosomes very much in the same way as beads are strung along a string. Thus the hereditary constitution consists of definite chemical units, united in constant proportion and position, and combining to make the development of the individual proceed in just one particular way, providing the development takes place in a *normal environment.*

Each species has a constant number of chromosomes. Man and the tobacco-plant have forty-eight, the rat has sixteen, the lily twenty-four, etc. The shapes of the chromosomes are also characteristic for each species.

The presence of such an elaborate mechanism for the precise halving of the chromosomes makes one feel sure that they have a very important function which requires them to retain their individuality and equality. Competent biologists are agreed that they are the tangible bearers of heredity, capable of being counted and measured. They are the sole determiners of the differences among the higher animals, including man.

By a complicated process of division the germ cells have the number of their chromosomes reduced to one-half, just before they mature. This is shown diagram-

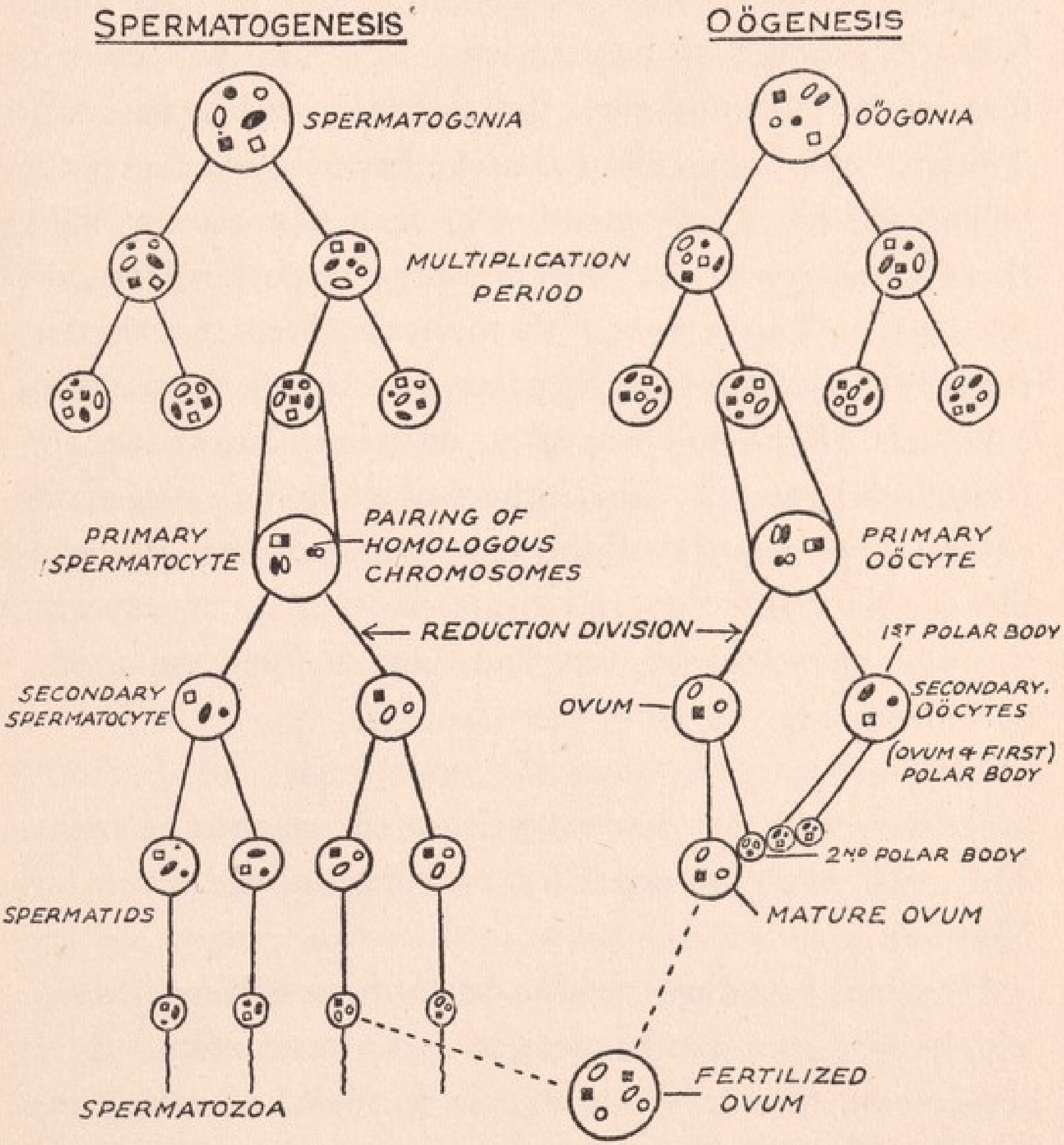

FIG. 3.—Maturation of Sperms and Ova.

matically in Fig. 3. Then, when an egg is fertilised, it will contain the number of chromosomes which is equal to the number normal to the species, half being derived from the male and half from the female element.

In man each body cell has forty-eight. During the reduction division in the formation of the germ cells the number of chromosomes is halved, so that each sperm and ovum contains only twenty-four. The fertilised egg, being a product of a sperm and an ovum, will contain forty-eight chromosomes, the normal number for man. Thus in each body cell of man we have twenty-four pairs of chromosomes, one member of each pair coming from the paternal germ cell, and the other member from the maternal. This agrees with the recognised fact that, as regards the definable characters which distinguish individuals of the same species, offspring inherit equally from both parents. This latter fact alone is a proof of the extreme importance of the chromosomes, for although the egg is many hundred times larger than the sperm, the egg chromosomes are no larger than the sperm chromosomes.

Having learned how the mechanism of heredity functions, we shall now investigate the genesis of twins. This can best be done by considering the work of Newman.

Newman [1] studied the nine-banded armadillo of Texas, which produces quadruplets at every pregnancy. It is also known that only one egg is fertilised at each pregnancy. He found that the members of a litter are always of the same sex, and that for a number of physical traits the coefficient of correlation [2] for 115 sets of quadruplets

[1] Newman, H. H., *The Physiology of Twinning*, and *The Biology of Twins*.

[2] A coefficient of correlation is the decimal fraction which tells what proportion of the causes affecting the magnitude of two variables is

was ·93. No coefficient of correlation of nearly this magnitude has ever been found for physical traits among individuals, except in the cases of identical twins and the right and left antimeric halves of a single individual.

We have here a crucial test of the biological principle of homology, which states that, generally, the degree of closeness of structural resemblance runs essentially parallel with the closeness of kinship. In the case of the armadillo quadruplets, and, as most biologists will agree, in the case of identical twins also, we have the closest possible genetic relationship and the greatest similarity of physical structure found in nature. It is worth noting too that when more distant relationships are measured, such as siblings, cousins, etc., resemblance decreases in proportion to decrease in kinship.

Consider now the mechanisms by means of which the two kinds of twins, identical and fraternal, are produced. The fraternal twins present no difficulty, since all the available evidence goes to show that these are simply cases of multiple birth. Two ova are fertilised by separate sperms and two embryos develop side by side, each having its own chorion and placenta. Owing to the variability of parental germ cells, their heredities will be different. With identical twins, however, one egg only is fertilised by a single sperm. This single zygote proceeds to divide mitotically, but at some stage, it may be at the first division (but always at a very early one), the growing cells divide into two halves, each of

---

common to both variables. 1·00 is complete correlation, the causes affecting both variables being identical.

which then proceeds to develop into a separate individual. These separate individuals are known as identical twins. They are always enclosed in the same fœtal membrane and are generally nourished by means of a single placenta. They have, perforce, the same hereditary constitution, since both arise from a single fusion of hereditary elements. Identical twins, therefore, are literally flesh of one flesh and bone of one bone. The marked resemblance of this type of twins is in itself a proof of the importance of the chromosomes as determiners of hereditary traits.

The variability of the germ cells is due to the fact that in man each contains twenty-four chromosomes, which are capable of forming among themselves 4,096 different combinations, each combination forming a different kind of germ cell. This assumes that the chromosomes maintain their individuality and that "crossing over" does not occur. As 4,096 varieties of paternal germ cells and the same number of maternal germ cells can occur, and since it is mere chance which determines the union of a particular pair of paternal and maternal germ cells, there are 16,777,216 total possible combinations of germ cells from each set of parents. But as human matings tend to have many traits in common, each being made, perhaps unconsciously, on the basis of community of physical as well as of mental traits, the potential variations within a particular family are reduced somewhat from the above theoretical total.

It is conceivable that occasionally (with our population and birth-rate, perhaps once in twenty years) a pair of fraternal, or biovular, twins might be born with identical chromosomal arrangements. More progressively frequent would be fraternal pairs differing by one, two, three, etc., chromosomes, until the average of sibling resemblance is reached. Then progressively less frequent would be pairs having even less resemblances than siblings. But it must be remembered that identical or uniovular twins always start out as halves, as it were, of one and the same mixture of hereditary material, while the fraternal or biovular twins start out differing in hereditary constitutions.

If we can distinguish the two types of twins, we thus have, as Galton shrewdly guessed before our knowledge of heredity had a scientific basis, individuals who have identical heredity and those who have not.

The infallible criteria for selecting these two types of twins are embryological. Authorities agree that the uniovular or identical twins are necessarily of the same sex and are always enclosed by a single chorion. The biovular or fraternal twins have two chorions and separate placentas, the latter often more or less fused, but even if fused showing no intercommunication of placental blood-vessels. Since this evidence is practically impossible to obtain a few years after birth, the only practical criterion is complete identity of structural resemblance. There is a possible chance that a fraternal pair might erroneously be placed in the identical group, but it would be a very rare occurrence.

After the data had been collected for the present study, Taku Komai[1] published the results of his work on the hand and feet patterns of twins. He states: "Such twins are identical twins in which the same hands or feet of different individuals are more alike than the different hands or feet of the same individual. But this statement must not be taken as involving the notion also that, if the former resemblance is less than the latter resemblance, the given twins are fraternal, since there are some twins which are apparently identical and yet do not show the condition mentioned above. Anyway this will probably serve as a criterion for identifying some identical twins."

[1] Komai, T., "A Criterion for Distinguishing Identical Twins from Fraternal Twins," *Science*, Vol. LXV, No. 1681, March 18, 1927, p. 280.

CHAPTER III

SUMMARY OF PREVIOUS STUDIES

Many persons who frankly admit the probability of the inheritance of physical traits, such as eye-colour, hair-colour, stature and cephalic index, become very sceptical when the field is extended to include mental traits as well. They may possibly go so far as to admit that such mental traits as animals possess are inherited, but man's mental traits are in a different category altogether. Yet a careful perusal of the evidence presented below will show that, so far as inheritance is concerned, no distinctions can be drawn between mental and physical traits.

Similarity of Abilities among Related Persons of Eminence.

The appearance of Darwin's *Origin of Species* in 1859 attracted Sir Francis Galton [1] to the problem of the inheritance of intelligence in man. He investigated the inheritance of great ability by studying the similarities of abilities among eminent men who were related to each other. He compiled a list of 977 eminent men, each of whom was the most eminent among 4,000 individuals. They were chosen from many professions—judges,

[1] Galton, F., *Hereditary Genius*, 1869.

statesmen, commanders, literary men, men of science, poets, musicians, painters, Protestant divines, modern scholars, oarsmen and wrestlers. He discovered the frequency with which these illustrious men had illustrious relatives and also the degrees of kinship they had with each other. He found that these 977 men possessed the following relatives of a like degree of eminence: 89 fathers, 114 brothers, 129 sons, 52 grandfathers, 37 grandsons, 53 uncles and 61 nephews, or a total of 535. Galton then showed that 977 ordinary men, selected by chance from the whole population, would have only four such eminent relatives. To refute the claim that environment and not heredity was the cause of the appearance or non-appearance of genius, he compared the nephews and more distant relatives (adopted sons) of popes with real sons of eminent men. He found the ability of the adopted sons was not nearly equal to that of the real sons of eminent men. He concluded as follows:

1. "That men who are gifted with high abilities—even men of Class E[1]—easily rise through all the obstacles caused by inferiority of social rank.

2. "Countries where there are fewer hindrances than in England to a poor man rising in life produce a much greater proportion of persons of culture, but not of what I call eminent men.

3. "Men who are largely aided by social advantages are unable to achieve eminence unless they are endowed with high natural gifts."

[1] By Class E Galton means a stage higher than the mass of men who obtain the ordinary prizes of life.

A number of faults are apparent in this study, but considering that it was the pioneer attempt in the investigation of a most difficult subject, they can be readily forgiven. Galton used unfair selection in his grouping, since he neglected to take into consideration all of the members of a given group. He also assumed that the real measure of a man's ability was given by contemporary public opinion. Judges, for example, are often appointed for political reasons. The theory that "genius will out," which he held, has not been proven. Very bad environment can undoubtedly destroy great hereditary possibilities.

Galton [1] showed later, as a result of a study of Fellows of the Royal Society, that outstanding parents have eminent children much more frequently than the average of the population. This was confirmed in a similar study by Galton and Schuster,[2] when they obtained their data from Fellows of the Royal Society whose names appeared in the *Year Book* for 1904. They concluded: "The demand for exceptional ability, when combined with energy and good character, is so great that a lad who is gifted with them is hardly more likely to be overlooked than a bird's nest in a playground of a school."

Woods [3] studied 671 members of the royal families in Europe. He eliminated the influence of selection by including all of the members of the families he studied. However, he used a subjective method of grading them

[1] Galton, F., *English Men of Science*, 1874.
[2] Galton and Schuster, *Noteworthy Families*, 1906.
[3] Woods, F. A., *Mental and Moral Heredity in Royalty*, 1906.

on a scale of 1 to 10, in which 10 represented great ability, and 1 exceedingly low ability bordering on imbecility. He was the sole judge, rating the individuals according to reports of them given in histories and biographies. He found that particular values with regard to intellect existed in groups. High values centred around Frederick the Great of Prussia, Gustavus Adolphus of Sweden, and Isabella of Castile; low values clustered around George II of England, Louis XVI of France, and in the royal lines of Spain and Russia, where degeneracy has persisted for many generations. He computed the coefficients of correlation for different degrees of relationship. These are the results for intelligence:

Parent and child, 504 pairs . . .	$r = \cdot 3007 \pm \cdot 0472$
Grandparent and child, 952 pairs . .	$r = \cdot 1506 \pm \cdot 0369$
Great-grandparent and child, 179 pairs .	$r = \cdot 1528 \pm \cdot 0332$

Woods concluded that hereditary traits and abilities persisted in families to a marked degree, in spite of varying environmental influence. He stated: "It would seem we are forced to the conclusion that all these rough differences in intellectual activity which are susceptible of grading on a scale of ten are due to predetermined differences in the primary germ cells." He further added: "At least 90 per cent. of the intellectual side of character is due to heredity," but this is hard to credit when his coefficients of correlation are so low. But, as before stated, the chief criticism of this study is the lack of a valid measuring instrument for mental and moral qualities, and in view of the smallness of his coefficients, it is difficult to understand him ascribing 90 per cent. to heredity.

Schuster and Elderton[1] studied the relationship between a father's success at Oxford and his son's success later at the same college. They obtained the following results:

From Oxford Class Lists.

Degree at Oxford taken by father.	Percentage of sons who took I and II Class Honours.
I and II	27
III	15
Pass	12
None	9

They assumed that on the whole intelligence and success in the final schools at Oxford were highly correlated and that intelligence and the grade reached in a public school were also highly correlated. Health and perseverance are also necessary, but intelligence is a *sine quâ non* for success in the Oxford finals. Fathers and sons only were considered, as they have a fairly uniform environment. There was no lack of the necessities of life, and all came from cultured homes. For filial resemblance, the coefficient of correlation was ·31 ; for fraternal, ·40.[2]

[1] Schuster, E., and Elderton, E., *The Inheritance of Ability*, Eugenics Laboratory Memoirs, 1907.

[2] Miss Elderton also obtained a coefficient of correlation of ·27 between cousins, based on the record of 300 families.

Similarities of Abilities among Related Defective and Low-grade Persons.

Dugdale [1] and Goddard [2] used a type of study in which all the available data concerning a single family were investigated. Dugdale found that a bad mental and moral stock produced a much larger proportion of inferior mental and moral offspring than did a superior stock.

Goddard, while working at the Vineland Institution for the Feeble-minded, New Jersey, traced back the ancestry of an inmate, Deborah Kallikak, for five generations. Her earliest progenitor to be studied was Martin Kallikak, a man of good ability, living at the time of the American Revolution. Joining one of the Militia companies and being quartered at a town, he met a feeble-minded girl by whom he had an illegitimate son, who was given the name of his father. This Martin junior married a degenerate woman, and from the line thus established Goddard was able to trace 480 direct descendants, as follows: 143 feeble-minded, 102 unknown, 36 illegitimates, 33 prostitutes, 24 alcoholics, 3 epileptics, 82 who died in infancy, 3 criminals, and 8 keepers of disorderly houses. Only 46 were found normal.

When Martin Kallikak senior returned from the war he married a woman of normal intelligence. From this union there were 406 descendants during the same period of time. All were normal with the exception of five, of

[1] Dugdale, R. L., *The Jukes*, Thirty-third Annual Report of the Prison Association of N. Y., 1876.

[2] Goddard, H. H., *The Kallikak Family*, 1912.

whom one was feeble-minded, two were alcoholic, one was sexually immoral, and one a religious maniac. There were no epileptics or criminals, and all the normal individuals were good citizens, including doctors, lawyers, educators, judges and business men.

Goddard's findings, therefore, are very similar to Dugdale's.

Such studies of feeble-mindedness as these are open to the criticism that the degree of feeble-mindedness is not objectively and accurately determined. So far as we know, it may be that the children of feeble-minded parents are not as defective as their parents. When the investigator is looking for further defects, he asks questions tending to reveal them, neglecting, perhaps, to bring out the normal aspects of the subjects whom he is investigating. When the ratings given to an individual are based indirectly on the testimony of relatives or acquaintances, they are subject to very great errors, and if the ratings are for individuals who are long dead, they are still more unreliable.

Some may argue that low intelligence persists in a given family because its members were born in circumstances not favourable for the development of that mental ability which is necessary for success. But it seems reasonable to believe that a person's ability largely determines the sort of environment in which he is content to live. Numbers of eminent men have pushed themselves forward and found a way out of the impoverished environment into which they were born. "They break their birth's invidious bars."

Similarities between Brothers and Sisters.

The foregoing studies have concerned themselves with the inheritance of either talent or feeble-mindedness among all the members of the families considered. We shall now record studies made of the similarities of children of the *same* parents.

Pearson [1] investigated the laws of inheritance in man with regard to physical, mental and moral traits among individuals of the ordinary type, excluding the exceptionally gifted and the feeble-minded classes. The results concerning the physical traits for one thousand families are given in Table I.

TABLE I.

Inheritance of Physical Characteristics (Pearson).

A. Adults.

Character.	Correlation.		
	Brothers.	Sisters.	Brothers and sisters.
Stature	·51	·54	·55
Span	·55	·56	·53
Cubit (length of fore-arm).	·49	·51	·44
Eye colour . . .	·52	·45	·46
Mean	·52	·51	·49

[1] Pearson, K., "On the Laws of Inheritance in Man," *Biometrika*, Vol. III, pp. 131–90.

Also, Pearson, K., "On the Relationship of Intelligence to Size and Shape of Head and to Other Physical and Mental Characters," *Biometrika*, Vol. V, pp. 105–46.

B. School-children.

Character.	Correlation.		
	Brothers.	Sisters.	Brothers and sisters.
Health	·52	·51	·57
Eye colour	·54	·52	·53
Hair colour	·62	·57	·55
Cephalic index	·49	·54	·43
Head length	·50	·43	·46
Head breadth	·59	·62	·54
Head height	·55	·52	·49
Mean	·54	·53	·51
Athletic power	·72	·75	·49

Pearson obtained information regarding the intelligence of siblings from many schools, using a sixfold division of intelligence : A—very dull ; B—slow dull ; C—slow ; D—slow intelligent ; E—intelligent ; F—quick intelligent.

He found that if a group of boys with slow dull intelligence were investigated, then the average intelligence of the brothers of these boys was in the slow dull group, and that the brothers did not even reach the middle of that group. Similarly, the brothers of boys in the intelligent group were found to fall just within the intelligent group.

Table II shows the results for intelligence, together with those for certain physical traits not subject to the influence of environment.

TABLE II.

Correlations for Physical and Mental Traits (Pearson).

Character.	Correlation.		
	Brothers.	Sisters.	Brothers and sisters.
Head length . . .	·50	·43	·46
Head height . . .	·55	·52	·49
Eye colour . . .	·54	·52	·53
Intelligence . . .	·52	·50	·49

All the coefficients of correlation in the above table are practically the same, differences of ·05 or ·06 being insignificant.

It has been maintained by some that the brothers were alike because of the similarity of their environment. We shall give Pearson's own answer to this contention:

"It is conceivable that all inheritance is at the same rate, but it is not conceivable that all environmental influence is at the same rate. If the resemblance between brothers is the same for eye and for ability, we are forced (i) to conclude that this resemblance is all due to inheritance; or (ii) we are forced to conclude that they are both inherited at lower rate, and environment makes up the common difference to the observed degree of resemblance; or (iii) we must believe, as most people, I think, do, that, ability and moral character being more subject to environment, there is some small environmental influence on eye colour and a large influence on the psychical characters, which gives a total equal resemblance. If the third view is held, it is necessary to explain why environment, for a great variety of characters, *just* supplements a lessened heredity to make up a sensibly constant degree of resemblance. Without this explanation, Occam's razor (law of parsimony) cuts off this view. If the second alternative is accepted, then eye colour and the psychical characters are inherited to the same extent. In that case you may hope to modify the mental character of a stock as successfully as you may the eye colour of the children of brown-eyed parents."

The only conclusion that can be drawn from the facts is that mental and physical traits seem to be inherited to the same degree.

Starch [1] attempted to determine (1) the extent to which siblings are alike in mental traits; and (2) whether the similarity is greater in those tests directly affected by training in school work than in those which are not directly affected by school work.

He used tests of reading, including speed, comprehension, and size of vocabulary; tests of handwriting for speed and quality; spelling tests; and arithmetic tests. Perception tests and tests of memory for words read were used as tests of mental functions. Motor capacity was measured by a tapping test.

He computed his correlations by the Spearman rank method, obtaining an average coefficient of ·42 for the tests directly affected by school work, and a coefficient of ·38 for those tests little affected by school work. Since these are practically the same, he concluded that the resemblances found in siblings must be due to heredity.

Using intelligence quotients, obtained by the Stanford

[1] Starch, D., "The Similarity of Brothers and Sisters in Mental Traits," *Psychological Review*, 1917, Vol. XXIV, pp. 235–38.

Revision of the Binet Scale, as measures of intelligence, Gordon[1] found a Pearson coefficient of correlation of ·53 when 91 pairs of orphan siblings were compared. Later,[2] for 216 pairs of orphan siblings she obtained a correlation of ·61.

Elderton[3] re-investigated the facts contained in Gordon's data. Gordon had used no child more than once in forming pairs of siblings. Elderton formed all the pairs possible from the data and found the correlation was reduced to $\cdot 467 \pm \cdot 026$. She also obtained a correlation of $-\cdot 31 \pm \cdot 028$ between chronological age and the I.Q.'s, and directed attention to the fact that it is unsafe to draw any conclusions of either a hereditary or an environmental nature from results based on I.Q. data unless the effect of age is first eliminated.

Elderton[4] then collected data from English school-children, using intelligence tests and teachers' estimates of the intelligence of the pupils. She obtained the results given in Table III.

Miss Elderton believed that her results led to the conclusion that the limits set to ability were due to heredity rather than to environment.

Madsen[5] found a correlation of $\cdot 63 \pm \cdot 05$ between

[1] Gordon, K., " Psychological Tests of Orphan Children," *Journal of Delinquency*, Jan. 1919, Vol. XVIII, pp. 46–55.

[2] Gordon, K., *The Influence of Heredity on Mental Ability*, Report of the Children's Dept., State Board of Control of California, 1918–20.

[3] Elderton, E.M., " A Summary of the Present Position with Regard to the Inheritance of Intelligence," *Biometrika*, 1923, Vol. XIV, pp. 378–408.

[4] Elderton, E.M., *op. cit.*

[5] Madsen, I. N., " Some Results with the Stanford Revision of the Binet-Simon Tests, *School and Society*, May 10, 1924, p. 559.

TABLE III.

Intelligence of Siblings (Elderton).

Siblings uncorrected for age.	School A.		School B.	
	I.Q.	Teachers' estimate.	I.Q.	Teachers' estimate.
Brother-brother . . .	·669 ± ·053	·768 ± ·04	·394 ± ·055	·351 ± ·057
Sister-sister . . .	·272 ± ·06	·45 ± ·052	·461 ± ·065	·46 ± ·065
Brother-sister . . .	·326 ± ·044	·543 ± ·036	·449 ± ·036	·466 ± ·033

63 pairs of siblings whose Binet intelligence quotient he had calculated. He also paired at random 63 children in one school with 63 in another, and found a correlation of −·04. He concluded that intelligence runs in families.

Hart[1] found correlations for intelligence of ·447 ± ·034 for 252 pairs of urban children and of ·459 ± ·066 for 147 pairs of rural children. The urban children tried the Army Alpha, National and Stanford-Binet, while the rural children tried only the Stanford-Binet. A selected group of children in the University of Iowa schools was given the Stanford-Binet also. For 219 pairs the correlation was ·399 ± ·057. Hart noted the tendency of intelligence to run in families, but occasionally large variations were found among children of the same family.

Hildreth,[2] using intelligence quotients obtained by the Stanford-Binet, and educational and achievement quotients obtained from the Stanford Achievement Test,

[1] Hart, H., "Correlations between Intelligence Quotients of Siblings," *School and Society*, Sept. 20, 1924, Vol. XX, No. 508.

[2] Hildreth, G. H., *The Resemblance of Siblings in Intelligence and Achievement*, 1925.

computed the resemblance found among siblings in intelligence and achievement. Her results are stated briefly as follows:

"Correlations ranging from ·27 to ·68 were found for intelligence of true sibs reared together. The variations are due to differences in the number of cases involved, differences in central tendency, variability within each group, and variations in chronological ages of the individuals comprising the different groups. No one coefficient of correlation for intelligence can be given from the data obtained. It appears to be greater than ·3 and less than ·7. Resemblance in intelligence and achievement for random pairings of unrelated children cluster around zero. Unrelated children reared in the same environment (an orphan home) 10 to 25 per cent. of their lives show, when paired at random and correlated for I.Q., a correlation of $-{\cdot}103 \pm {\cdot}10$ for 47 pairs. Similar children reared together for 50 to 100 per cent. of their lives resemble each other to the extent of $-{\cdot}169 \pm {\cdot}10$ for 47 pairs. All these correlations are negligible. Rearing a group of children together for 50 to 100 per cent. of their lives does not tend to make them resemble each other any more closely than if they had been kept apart. But the small number of cases precludes the finality of any conclusions. In traits subject to training, such as those measured by the achievement test, no more resemblance is found than in traits not subject to the influence of the school."

Miss Hildreth's main results are shown in Table IV.

Since Miss Hildreth did not use a method which took into account both the amount of correlation found between the members of a group and the variability of the group (as the standard error of estimate would have done), it is difficult to compare the results of her various groups

TABLE IV.

Intelligence and Achievement of Siblings (Hildreth).

A. TRUE SIBS.

1. *Intelligence (I.Q.'s).*

Group.	S.D.	*r.*	Mean difference.	No. of pairs.
Oklahoma . .	18·35	·629 ± ·02	12·07	450
Horace Mann School	15·25	·274 ± ·03	14·02	325
Hebrew orphans .	14·05	·322 ± ·04	12·70	253
Composite . .	21·27	·679 ± ·01	12·93	1028
2. *Achievement (E.Q.'s).*				
Oklahoma . .	17·65	·579 ± ·04	13·05	105
Horace Mann School	13·40	·418 ± ·06	11·93	83
Composite . .	17·05	·579 ± ·03	12·49	188
3. *Accomplishment (A.Q.'s).*				
Oklahoma . .	10·50	·269 ± ·06	9·52	105
Horace Mann School	10·95	·156 ± ·07	10·90	83
Composite . .	12·05	·320 ± ·04	10·21	188

B. RANDOM PAIRING (COMPOSITE OF ALL GROUPS).

I.Q.'s	$r = ·156 \pm ·06$ . . .	100 pairs.
E.Q.'s	$r = ·0079 \pm ·10$ . . .	50 "
A.Q.'s	$r = ·022 \pm ·10$ . . .	50 "

RANDOM PAIRINGS OF ORPHANS (I.Q.'s). ALL UNRELATED.

Reared together 10– 25 per cent. of their lives	$r = - ·103 \pm ·10$
" " 50–100 " " "	$r = - ·169 \pm ·15$

with each other. It will be noted that generally her correlations are high when her standard deviations are high, and vice versa. A composite measure of these two variables would give a true comparison of the resemblances found among the groups.

In all the studies thus far cited it has been impossible to separate the effect of heredity from the environmental effect with any degree of certainty. We shall, therefore, turn to studies made of twins, hoping to find some light shed on the problem from this source.

Studies of Twins.

It is necessary to retrace our steps again to Galton, who was the first to draw attention to the two types of twins, identical and fraternal. He compared a group of 35 pairs, reported as being very similar, with another group of 25 distinctly dissimilar pairs. He had no objective data to work with, using only statements made by the parents, which are of little scientific value. However, Galton's reputation as an eminently fair scientist makes his conclusions well worth quoting.[1]

"We may, therefore, broadly conclude that the only circumstance, within the range of those by which persons of similar conditions of life are affected, that is capable of producing a marked effect on the character of adults, is illness or some accident that causes physical infirmity. . . . The impression that all this leaves on the mind is one of some wonder whether nurture can do anything at all, beyond giving instruction and professional training. There is no escape from the conclusion that nature prevails enormously over nurture when the differences of nurture do not exceed what is commonly to be found among persons of the same rank of society in the same country. My fear is that my evidence may seem to prove too much, and be discredited on that account, as it appears contrary to all experience that nurture should go for so little."

Thorndike [2] was the first to use objective measurements

[1] Galton, F., *Inquiries into Human Faculty*, 1883, pp. 168 and 172.
[2] Thorndike, E. L., *Measurement of Twins*, 1905.

in the study of twins. He chose 50 pairs of twins at random from the children in the New York City schools and gave them 14 tests, 8 physical and 6 mental. He found the correlations given in Table V for mental traits.

TABLE V.

Resemblance of Twins in Mental Traits (Thorndike).

Test.	Twins.	Siblings.	Younger twins.	Older twins.
Cancellation of A's . .	·69	·32	·66	·73
Cancellation of *a–t* and *r–e*	·71	·29	·81	·62
Misspelled words . .	·80	—	·76	·74
Addition . . .	·75	—	·90	·54
Multiplication . . .	·84	—	·91	·69
Word opposites . .	·90	·30	·96	·88
Average	·78	—	·83	·70

He argued thus: "If these resemblances are due to the fact that the two members of a twin pair are treated alike at home, have the same parental models, attend the same school and are subject in general to closely similar environmental conditions, then, (1) twins should, up to the age of leaving home, grow more and more alike; (2) if similarity in training is the cause of similarity in mental traits, ordinary fraternal pairs not over four or five years apart in age should show a resemblance somewhat nearly as great as twin pairs, for the home and school conditions of a pair of the former will not be much less similar than those of the latter; (3) if training is the cause, twins should show greater resemblance in the case of traits much subject to training than in traits less subject to training. On the other hand, (1) the nearer the resemblance of young twins comes to equalling that of old, (2) the greater the superiority of twin resemblance to ordinary fraternal resemblance is, and (3) the nearer twin resemblance in relatively untrained capacities comes to equalling that in capacities at which the home and school direct their attention, the more must the resemblances found be attributed to inborn traits."

All the results favoured the factor of heredity. In both the mental and physical tests the resemblances of twins were much greater than those of siblings, and the resemblances did not alter with age or training. The average *r* for twins was about ·78, while Pearson found the average *r* for siblings to be about ·50. Thorndike concluded that "the mental likeness found in the case of twins and the differences found in the case of non-fraternal pairs, when the individuals compared belonged to the same age, locality and educational system, are due, to at least nine-tenths of their amount, to original nature." He also states: "The facts then are easily, simply and completely explained by one simple hypothesis, namely, that the natures of the germ cells—the conditions of conception—cause whatever similarities and differences exist in the original natures of men, that these conditions influence mind and body equally, and that in life the differences produced by such differences as obtain between the environments of present-day New York City public school children are slight."

Thorndike, realising the weakness of Galton's method of verbal reports, used a series of mental tests, which, however, have since been shown to be unreliable as measurements of general intelligence. He is also a little in doubt as to whether the possible effects of home and school training have been entirely eliminated. But he carefully states that his results hold only for such measurements as he made.

No other study of twins appeared until Merriman's in 1924.[1] He measured only the general intelligence of the twins, using the Stanford-Binet, Army Beta, National Intelligence, and teacher estimates. Merriman compared the resemblances of young and old twins and obtained the following relations:

TABLE VI.

Resemblance of Twins in Intelligence (Merriman).

Group.	Binet I.Q.	Beta scores.	N.I.T. scores.	Teacher.
All pairs 5–9 yrs.	·809 ± ·032	·784 ± ·049	·797 ± ·034	·686 ± ·057
All pairs 10–16 yrs.	·757 ± ·037	·664 ± ·054	·875 ± ·017	·373 ± ·081
All twin pairs	·782 ± ·025	·841 ± ·022	·891 ± ·011	·512 ± ·053
Like-sex 5–9 yrs.	·882 ± ·028	·921 ± ·025	·946 ± ·012	·788 ± ·053
Like-sex 10–16 yrs.	·865 ± ·027	·842 ± ·036	·865 ± ·022	·568 ± ·083
All like-sex pairs	·867 ± ·020	·908 ± ·017	·925 ± ·009	·654 ± ·053
Girl-girl pairs 5–9 yrs.	·915 ± ·026	·709 ± ·112	·965 ± ·009	·913 ± ·030
Girl-girl pairs 10–16 yrs.	·814 ± ·05	·896 ± ·032	·919 ± ·021	·521 ± ·123
All girl-girl pairs	·857 ± ·029	·866 ± ·033	·928 ± ·012	·645 ± ·071
Boy-boy pairs 5–9 yrs.	·800 ± ·078	·934 ± ·049	·921 ± ·041	·534 ± ·161
Boy-boy pairs 10–16 yrs.	·890 ± ·034	·747 ± ·080	·895 ± ·027	·715 ± ·089
All boy-boy pairs	·877 ± ·030	·938 ± ·015	·925 ± ·018	·605 ± ·090
Unlike-sex pairs 5–9 yrs.	·774 ± ·064	·519 ± ·147	·753 ± ·066	·681 ± ·090
Unlike-sex pairs 10–16 yrs.	·298 ± ·137	·643 ± ·091	·834 ± ·044	·072 ± ·141
All unlike-sex pairs	·504 ± ·081	·732 ± ·056	·867 ± ·025	·266 ± ·102

Merriman's main conclusions are:

[1] Merriman, C., "The Intellectual Resemblance of Twins," *Psychological Review*, 1924, Vol. XXXIII, Monograph 5, pp. 1–58.

(1) " Environment appears to make no significant difference in the amount of twin resemblance. Older twin pairs are no more alike than younger twin pairs."

As the teacher-rating method is known to be very unreliable, we shall neglect the results obtained by it. But if we consider the data obtained by the three other

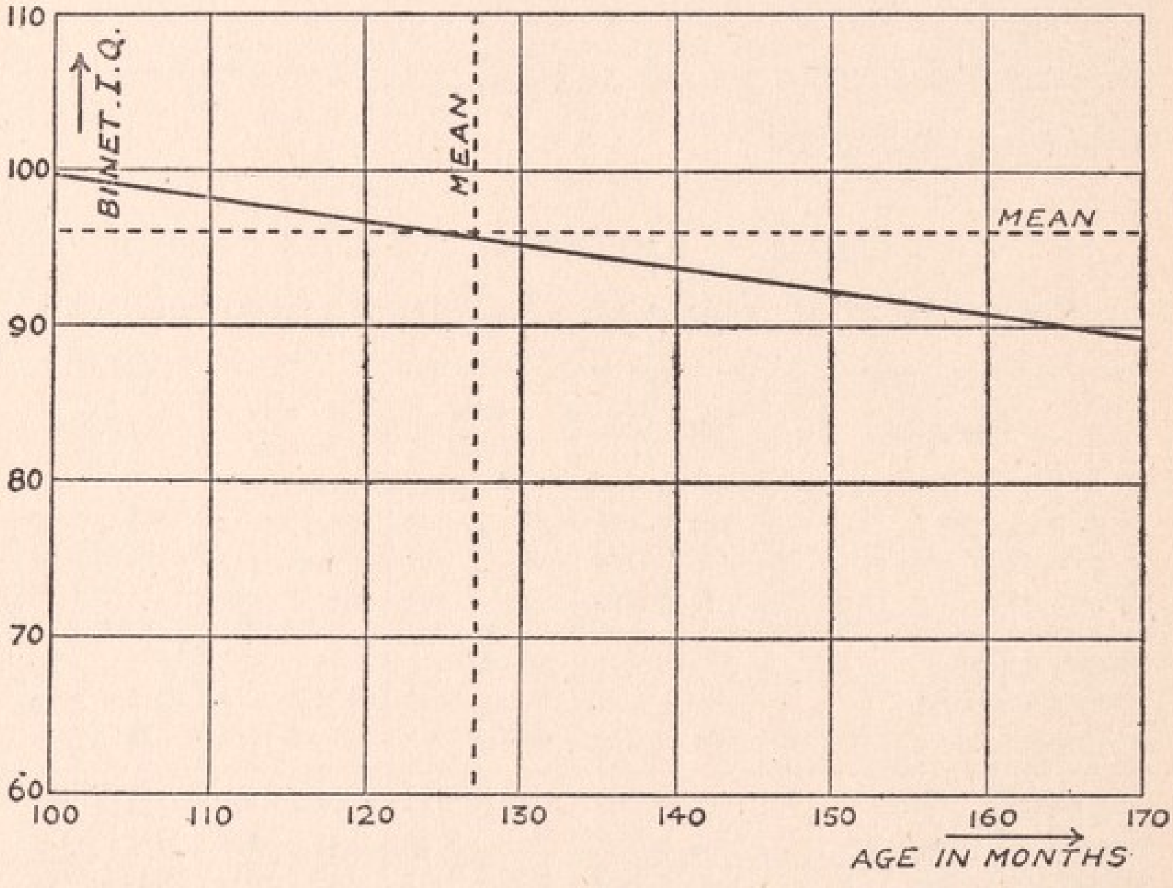

FIG. 4.—Regression of I.Q. on Age for Merriman's Twins: Ages 6–15 years.

methods, we are unable to agree that this conclusion of Merriman has been proved. Except in the case of the Binet results, where I.Q.'s are used, he has not eliminated the effect of age on the amount of resemblance obtained. He would find that if unrelated children are paired for age, a significant amount of correlation would be apparent.

In order to discover if Merriman had obtained spurious correlations through neglecting the effect of age on the I.Q., the writer calculated the coefficient of correlation between the chronological ages and the I.Q.'s of 204 twins, whose ages were from 6 to 15 years, and to whom Merriman had given the Stanford-Binet test. A correlation of $-\cdot29 \pm \cdot043$ was found. This means that there is a gradual decrease in intelligence with age. This is shown graphically in Fig. 4.

It is obvious that before any definite conclusions can be drawn from Merriman's correlations the effect of age on the magnitude of these correlations should be eliminated.

Another important factor which must be considered in comparing correlation coefficients is the range and variability of the different groups. Increase in range of the ability measured generally results in an increase in the size of the coefficient of correlation. The coefficients given in this study are therefore not absolutely comparable, and this may account for some of the variations found.

(2) "Twins suffer no intellectual handicap."

(3) "The data show that there are two types of twins, because (*a*) the correlation of like-sex pairs is higher than unlike-sex pairs; (*b*) sibling data, when compared with twin data, show that the correlations for siblings is much nearer the unlike-sex twin data than the like-sex twin data; (*c*) all the curves and curve-fitting tests indicate clearly a difference between like- and unlike-sex pairs; (*d*) the study of verbal reports on 'similar pairs' tends strongly to show that curve differences are to be largely accounted for by the like-sex pairs that show great intellectual and physical similarity, and that presumably belong to the 'duplicate type.'"

Shen[1] calculated from Merriman's data the standard deviation of the Binet I.Q.'s for the various groups and also the standard errors of estimate. He found that the older twins were a more variable group, except the unlike-sex pairs, where correlation is especially low for the older ages. But as there are only 20 pairs in this group, not much weight can be given to the results obtained from it. The standard deviations which Shen found balance the irregularities of the correlation coefficients, the resulting standard errors of estimate ($\sigma\sqrt{1-r^2}$) being very consistent, showing an increase of three points from the younger to the older group.

Shen's treatment of the Binet I.Q.'s found by Merriman for his twins gives the results shown in Table VII.

Owing to the fewness of the pairs it is unsafe to draw definite conclusions, except in the cases where more than 30 pairs are included in a group. If all the twin pairs are considered, it is seen that the resemblance between the younger twins is much greater than that between the older ones. If the reliability of the I.Q. does not decrease with age, or if the variability of the I.Q. does not increase (*i.e.* older children have a distribution of their I.Q.'s, with a larger dispersion than younger children), then the difference found must be due to the increasing effect of the environment from the lower to the upper ages.

Lauterbach[2] collected data on twins, using such tests as the Terman Group Test of Mental Ability, the National

[1] Shen, E., "The Intellectual Resemblance of Twins," *School and Society*, May 1925, Vol. XXI, No. 542.

[2] Lauterbach, C. E., "Studies in Twin Resemblance," *Genetics*, Nov. 1925, Vol. X, No. 6, pp. 525–68.

TABLE VII.

Resemblance of Merriman's Twins (Shen).

Group.	r.	σ.	$\sigma\sqrt{1-r^2}$.	No. of pairs.
All twin pairs . . .	·782	15·1	9·4	105
Pairs 5–9 yrs. . . .	·809	13·0	7·6	47
Pairs 10–16 yrs. . .	·757	16·3	10·6	58
Like-sex pairs . . .	·867	16·5	8·2	67
Like sex 5–9 yrs. . .	·882	13·4	6·3	29
Like-sex 10–16 yrs. . .	·865	18·2	9·1	38
Girl-girl pairs . . .	·857	15·9	8·2	40
Girl-girl 5–9 yrs. . .	·915	15·0	6·1	19
Girl-girl 10–16 yrs. . .	·814	15·4	9·0	21
Boy-boy pairs . . .	·877	16·6	8·0	27
Boy-boy 5–9 yrs. . .	·800	9·7	5·8	10
Boy-boy 10–16 yrs. . .	·890	19·6	8·9	17
Unlike-sex pairs . .	·504	12·4	10·7	38
Unlike-sex 5–9 yrs. . .	·774	12·2	7·7	18
Unlike-sex 10–16 yrs. .	·298	11·6	11·1	20

Intelligence Test, the Thorndike-McCall Reading Scale, and the Courtis Arithmetic Tests, for testing mental ability. He also made such physical measurements as weight, height, cephalic index, handedness, and palm patterns. Although two tests of intelligence were used, each was given to different sets of twins, and thus there was no increase in the reliability of the results through using two tests.

He found the average coefficient of correlation practically the same for younger and older twins for the mental traits measured. Table VIII shows his results.

TABLE VIII.

Older versus *Younger Twins. About* 100 *Cases in Each Group* (*Lauterbach*).

Trait.	90–156 months.	157–238 months.	Difference.
Intelligence quotients . .	·64	·73	+·09
Reading quotients . . .	·44	·57	+·13
Arithmetic, accuracy . . .	·59	·50	−·09
Arithmetic, speed . . .	·59	·57	−·02
Memory for digits . . .	·36	·34	−·02
Handwriting, quality . . .	·49	·58	+·09
Handwriting, speed . . .	·66	·55	−·11
Averages	·54	·55	+·01

Lauterbach also found that, in general, like-sex pairs of twins show greater similarities than do unlike-sex pairs, but noted the fact that the difference in sex causes each member of the latter pairs to be brought up in a somewhat different environment. His average correlation for like-sex twins for all mental traits was ·57, while for the unlike-sex twins it was ·33. These are much lower than Thorndike's ·80 for all twins and Merriman's average of ·84 for like-sex pairs and ·59 for unlike-sex pairs. However, Lauterbach's correlations of ·77 for like-sex pairs and ·56 for unlike-sex pairs for intelligence quotients approximate those found by Thorndike and Merriman.

When he considered the resemblances in those traits that are much subject to training, Lauterbach found the evidence conflicting; in some traits the resemblances were great and in others small.

The correlations Lauterbach obtained for the physical traits are given in Table IX. They have a much higher degree of reliability than the measurements of mental traits.

TABLE IX.

Physical Traits of Twins (Lauterbach).

Trait.	Like-sex.	Unlike-sex.	Younger.	Older.
Height, standing .	·80	·53	·61	·65
Height, sitting . .	·73	·59	·60	·58
Weight . . .	·89	·50	·59	·64
Cephalic index . .	·67	·59	·72	·61
Averages . . .	·775	·55	·63	·62

Finally, it may be stated that Lauterbach rejected the fact of symmetry reversal, either of the whorl of the hair or of handedness, as evidence of the monozygotic origin of twins, since unlike-sex pairs, as well as like-sex pairs, showed these phenomena. He also stated that palm patterns afford no certain means of identifying monozygotic twins, since unlike-sex pairs may show identity of palm patterns.

Lauterbach's study, on statistical grounds, is open to the same criticism as Merriman's. No account is taken of the variability of the different groups compared, and many of the variations in his coefficients of correlation may be due to the differences in the ranges of the groups. Also, when group tests of intelligence are used, it is much more reliable to give more than one test when a fairly high degree of accuracy is desired in the results.

Further, to measure the average resemblance in traits much subject to training, it is better to give the best tests obtainable, from the point of view of reliability, and to use the *composite* score of the tests as measures of the individual's capacity in these acquired traits, since length of testing time greatly increases the reliability of the test.

Studies of Environmental Factors causing Eminence.

The principal studies that have been made from this standpoint are those of De Candolle (1873), Odin (1895), Ellis (1904 and 1926) and Cattell (1906). They all find that in any one nation eminent men are to be found in thickly-populated areas, especially cities; that their parents possess at least moderate financial means; and that most of them have received a good education. Odin believed that the number of eminent men could be increased very greatly by bringing all youths up in an intellectually active city (*e.g.* a university centre), requiring no labour from them until of a mature age, and giving all a good school training. But granting that the poorest soil will increase its yield somewhat if fertilised, will not the same stimulus given to rich soil multiply its yield many times? And may not one plausibly claim that the successful man's surroundings are but the secondary results of his parents' superior ability? It is owing to their parents' ability, ambition, perseverance and hard work that the educational facilities which children enjoy have been made possible. If men of high capacity go to urban areas to develop their abilities and make use of them, naturally their children will be born in cities. As

Thorndike[1] states, " If scientific and literary men are attracted to university cities, these cities will undoubtedly produce, on hereditary grounds alone, future scientific and literary men. The parents' achievement leads forward to these environmental conditions as truly as the son's achievement leads back to them."

In conclusion it may be stated that throughout the world's history great civilisations have grown up only where the people have been intelligent and possessed of great vigour. Was any great environment ever built by a race of fools ?

Defects in the Studies which have been Summarised.

The obvious defect in the earlier studies given in this chapter is the lack of objective methods of measuring mental traits. In the more recent studies which have utilised objective methods of mental measurement the chief objections are based on one or more of the following grounds :

1. Fewness of individuals comprising the various groups among whom comparisons are made.

2. Restricted range of ability within a group. The size of the coefficient of correlation depends greatly on the extent of the range of ability being measured.

3. Uncertainty as to whether the group being studied is a normal or a selected group.

4. The effect of age on the I.Q. is often disregarded, resulting in a spurious coefficient of correlation.

5. When group tests are used as measurements of

[1] Thorndike, E. L., *Educational Psychology*, 1914, Vol. III, p. 290.

intelligence, it is not safe to use I.Q.'s based on the application of a single group test.

6. In measuring ability in traits much subject to training, *e.g.* arithmetic, spelling, the tests used should be of the highest reliability obtainable.

7. The effect of the factors of heredity and environment are never separated with any degree of certainty, and it is therefore impossible to decide how much of the total resemblance found is inherited and how much is due to environment.

CHAPTER IV

NATURE OF THE POPULATION STUDIED AND THE TESTS WHICH WERE USED

1. *Description of the Population from which Data of Present Study were obtained.*

As pointed out in Chapter II, identical twins are the only individuals in the world who start out in life with identical heredities. They are not two different mixtures of the free and variable germ cells of their parents, but halves, as it were, of a single mixture. Fraternal twins, on the other hand, always start out with different heredities; they are really siblings born at the same time. If these two types of twins can be differentiated, we shall have ideal material for studying the relative effect of heredity and environment as causes of resemblances among individuals. Since we know that identical twins are always of the same sex, unlike-sex twins must always be fraternal ones. This simplifies the problem somewhat.

In order to get an unselected twin population to work with, 102 pairs of twins were selected at random from the public schools of Toronto and Hamilton. These were given thirteen mental tests in all—two for general intelligence, and eleven for traits much subject to training. The nature of these tests and the criterion by which they were selected will be described in the second part of this chapter.

It was also thought that some light might be thrown on the problem if the same tests as the twins tried were given to a number of children who had been brought up in an environment which was, as nearly as possible, uniform for all. Children reared in an orphanage fulfilled this condition, but owing to difficulty encountered in finding children who had spent at least 25 per cent. of their lives in such a home, the number obtained, 29, was not as large as could be desired. However, the results of the orphan children should have some significance when compared with the results from the twins.

Three distinct groups of children, therefore, were tested: (i) a group having identical heredity and practically the same environment (identical twins); (2) a group having similar but not identical heredities and practically the same environment (fraternal twins); and (3) a group having entirely different heredities but approximately the same environment for a definite portion of their lives (orphans).

2. *General Nature of the Tests.*

Since conclusions drawn from experimental data can be no more accurate than the original data on which the conclusions are based, no matter how refined the statistical treatment may be, it is essential to make the most accurate measurements that are possible throughout the experiment. Bearing this in mind, and remembering also that mental measurements are the most difficult of all to make, careful discrimination was used in the selection of the tests for measuring general intelligence and achievement in traits much subject to school training. Realising that the independent judgments of a number of competent persons are much more reliable than those of one only, the selection of the two principal tests, namely, the National Intelligence Test and the Stanford Achievement Test, was made on the basis of the combined but independent evaluations of seven of the most competent experts in the field of mental measurements—Otis, Trabue, Franzen, Freeman, Van Wagenen, McCall and Kelley. They recommend the two above-named tests as being superior to all others for use in the elementary schools, the N.I.T. being confined, of course, to pupils of nine years of age and upwards.

Since the N.I.T. is a group test, it was necessary to use another good group test in conjunction with it. In previous measurements of twins a combined rating obtained from two or more group tests had not been used. They suffer a lack of reliability on this account. It was therefore decided to use the composite intelligence quotient obtained by averaging the mental age from the National Intelligence Test with that from the Multi-mental Scale of McCall.

In standardising this latter scale, McCall used as a criterion the composite score obtained from the Stanford-Binet, National Intelligence Test, Scale A, Thorndike-McCall Reading Scale, Woody-McCall Mixed Fundamentals in Arithmetic, Morrison-McCall Spelling Scale, and ranking of pupils by expert teachers who had known them for a year. Since all the pupils on whom the scoring key is based had had since infancy ample educational opportunity and unusually strong motivation, it was proper for McCall to use educational tests in constructing an intelligence criterion. The final validity of the scale was obtained by comparing it with the Stanford-Binet and the National Intelligence Test, Scale A. These two and the Multi-mental Scale were correlated with the comprehensive and reliable criterion mentioned above. The correlation of the Multi-mental Scale with this criterion was ·93, while the National and Stanford-Binet correlations with the criterion were ·93 and ·89 respectively for pupils in grades 3 to 8. McCall finally estimated the correlations for thousands of pupils in grades 3 to 8 in a typical school to be ·93 for the Multi-mental, ·95 for the National and ·88 for the Stanford-Binet tests, when the three tests are given equal weight in the criterion.

The Stanford Achievement Test was chosen as the main instrument for measuring achievement. It consists of a battery of nine sub-tests: (1) Reading—paragraph meaning; (2) Reading—sentence meaning; (3) Reading—word meaning; (4) Arithmetic—computation; (5) Arithmetic—reasoning; (6) Nature Study and Science; (7) History and Literature; (8) Language Usage; (9) Spelling. The total testing time for this test is approximately 2½ hours. The test is highly reliable, the probable errors [1] of the scores being very small, as shown in the following table:

[1] The probable error of a score is a measure of the confidence that can be placed in the accuracy of the obtained score. It is the probable

Stanford Achievement Test.

Ages in years.	7.	8.	9.	10.	11.	12.	13.	14.	15.
Probable errors of educational ages in months .	1·1	1·6	1·6	1·5	2·0	2·1	1·9	2·1	2·1

Thus, the P.E. of the score of a 12-year-old child is about 2 months. If the educational age of such a child is found to be 12 years 6 months, then the chances are:

Even	that	12–6	is in error	by not	more than	2	months.
4 to 1	that	12–6	,,	,,	,,	4	,,
20 to 1	that	12–6	,,	,,	,,	6	,,
140 to 1	that	12–6	,,	,,	,,	8	,,

The best single index of a pupil's achievement is his educational age based on the composite score made on all the sub-tests in the battery. The subject age is not as reliable as the educational age, since it is based on a much shorter testing time. The reliability of the educational age, based on the composite score made on the Stanford Achievement Test, is exceedingly high, being ·98.

In order to check the results obtained with the Stanford Achievement Test it was decided to give also the two best achievement tests obtainable in two of the fundamental subjects of the elementary school curriculum, arithmetic and spelling. The two considered the most suitable were the British Columbia Test in the Fundamentals of Arithmetic and the Morrison-McCall Spelling Scale.

divergence of the obtained score of a pupil from his "true" score; *i.e.* his average score in a very large number of similar forms of the test—a number large enough to eliminate completely all errors of measurement arising from limited sampling of the pupil's knowledge.

There were thus thirteen tests in all used, the Multi-mental Scale, the National Intelligence Test, the nine tests comprising the Stanford Achievement Test, the B.C. Arithmetic Test, and the Morrison-McCall Spelling Scale, all being selected only after a careful examination of the tests available in each of the fields tested.

CHAPTER V

THE DATA

In the collection of the data all the tests were administered and scored by the writer. This led to uniformity in the methods used. The orphans were tested together at one time, while the twins were tested in groups the size of which depended on the number of twins found in a given school. Thus each member of a twin pair had exactly the same testing conditions to work under as his mate. The same is true for the orphans. Any slight errors introduced were therefore constant errors and would have no effect on the correlation results.

To obtain a true measure of the intelligence of an individual the scores from the Multi-mental Scale and the National Intelligence Test were first turned into their equivalent mental ages. The average of the two mental ages was then used to compute the intelligence quotient[1] of the individual. The reliability of an I.Q. calculated on the basis of two highly reliable intelligence tests is considerably greater than one based on the result of a single intelligence test.

The following procedure was adopted for measuring

[1] The intelligence quotient (I.Q.) is obtained by dividing an individual's mental age by his chronological age and multiplying by 100. I.Q. $= \frac{\text{M.A.}}{\text{C.A.}} \times 100$.

the ability of an individual in traits very much affected by training. The composite score made on the Stanford Achievement Test was transmuted into its equivalent *educational age* (E.A.), which represents the general educational development that an individual has reached. Thus, if a child's educational age is 12 years and 6 months, it means that he has attained a general educational development equal to that of the average child of 12 years and 6 months. Having obtained the child's educational age, two methods are possible to measure the rate of his progress in school. The first method utilises the *educational quotient*, and the second the *achievement quotient*.

The educational quotient is found by dividing an individual's educational age (obtained from an achievement test) by his chronological age and multiplying by 100 $\left(\text{E.Q.} = \frac{\text{E.A.}}{\text{C.A.}} \times 100\right)$.

The E.Q.'s may range from around 60 or 70 to 130 or 140, much as intelligence quotients do. An E.Q. considerably above 100 may be regarded as indicating superior intelligence, although perseverance and interest are contributing factors. Low intelligence cannot be safely inferred from a low E.Q., since the latter may be caused by many factors besides intelligence, *e.g.* irregular attendance, lack of interest and industry, poor teaching, and late entrance to school.

The second method of measuring an individual's attainment is by calculating his *achievement quotient* (A.Q.). This makes a comparison between the individual's educational status and his intellectual ability as measured by an intelligence test. If both the intelligence test and the achievement test are given on the same day, the A.Q. can be calculated by dividing the individual's educational age by his mental age and multiplying by 100 $\left(\text{A.Q.} = \frac{\text{E.A.}}{\text{M.A.}} \times 100\right)$. In the data reported in this study this method was used, since both intelligence and achievement tests were given on the same day. If, however, the tests had been administered on different days, it would have been necessary to calculate the A.Q. from the educational and intelligence quotients $\left(\text{A.Q.} = \frac{\text{E.Q.}}{\text{I.Q.}} \times 100\right)$. It may be noted in passing that the achievement quotient is not as reliable as either the intelligence quotient or the educational quotient, since it is affected by the probable errors of both the mental age and the educational age.

In the case of the two independent tests used for measuring spelling and arithmetical ability, the method of utilising their results was to convert the raw scores into T scores. The T scores were used for computing the resemblance in each of these subjects. As will be explained later, the effect of age on the scores was eliminated by the technique of partial coefficients of correlation.

As far as possible the following data were collected for each child:

Name, date of birth, chronological age, sex, grade, school, two mental ages based on two intelligence tests, composite score on the Stanford Achievement Test and educational age based thereon, and the T scores derived from the raw scores of the British Columbia Test in Arithmetic and the Morrison-McCall Spelling Scale. All of the original data are given in Appendices B and C.

Statistical Description of Twin and Orphan Groups.

A. Twin Group.

1. *Intelligence Quotients.*

The I.Q.'s for the 204 twins ranged from 63 to 146. The median I.Q. was 96·8, the mean 97·2, and the standard deviation 13·5. The chronological ages varied from 89 to 186 months.

Table X shows the frequency of the I.Q.'s for all the twins.

Table X.

Distribution of I.Q.'s of All Twins.

I.Q.	Frequency.
60– 69	3
70– 79	15
80– 89	44
90– 99	59
100–109	55
110–119	17
120–129	9
130–139	0
140–149	2
	N = 204
Median	96·8
Mean	97·2
S.D.	13·5

Merriman reported the median I.Q. of his twins as 97, and the mean as 96, with a standard deviation of 13·4.

Lauterbach's study shows his group of twins to have a mean of 95. Terman[1] reported the median I.Q. for 905 unselected children to be 99, with a standard deviation of 13·1. The writer's twin group, with a median I.Q. of 96·8 and a standard deviation of 13·5, conforms with remarkable closeness to Merriman's group. And since in many studies of unselected groups of children differ-

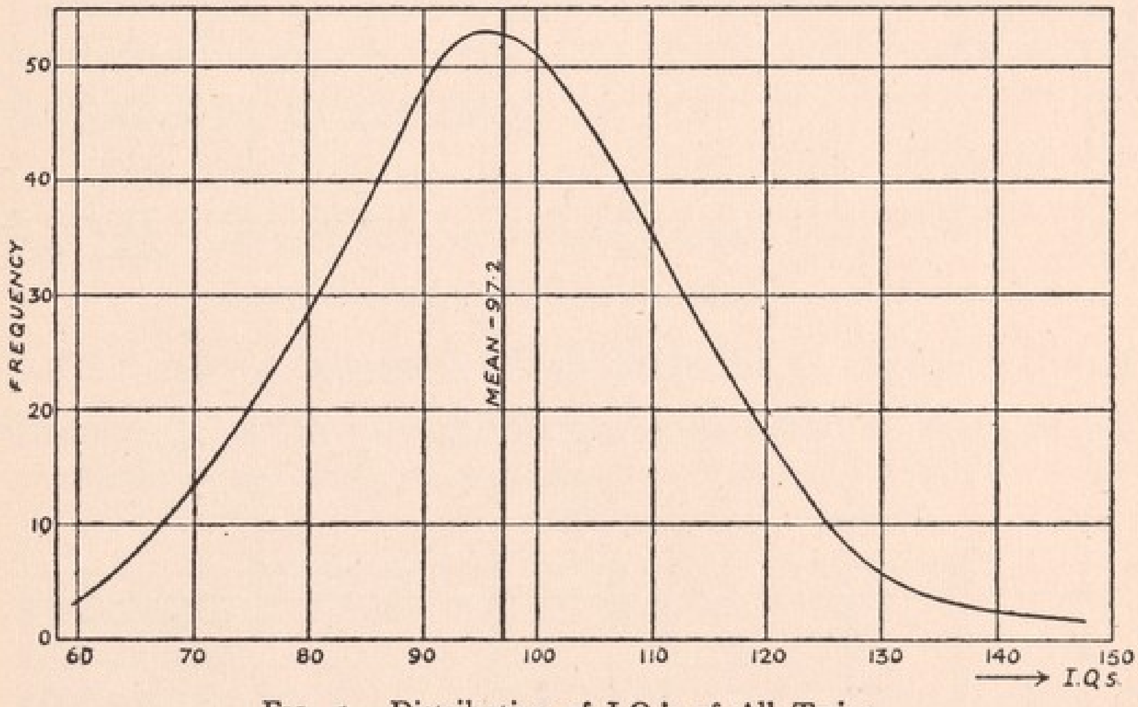

FIG. 5.—Distribution of I.Q.'s of All Twins.

ences of two points in the median I.Q. have been found, it appears that the present twin group shows no more deviation from the average than would many unselected groups of 200 non-twin individuals.

In Fig. 5 is shown the curve of distribution[2] of the I.Q.'s of the twin population studied. It can be seen that this curve approximates closely to the normal distribution of intelligence.

[1] Terman, L., *The Measurement of Intelligence*, 1916.

[2] All curves shown in this chapter have been smoothed once from the original data.

Besides being considered as a composite group, the twins were divided into a like-sex and an unlike-sex group, and also, on the basis of physical identity or dis-

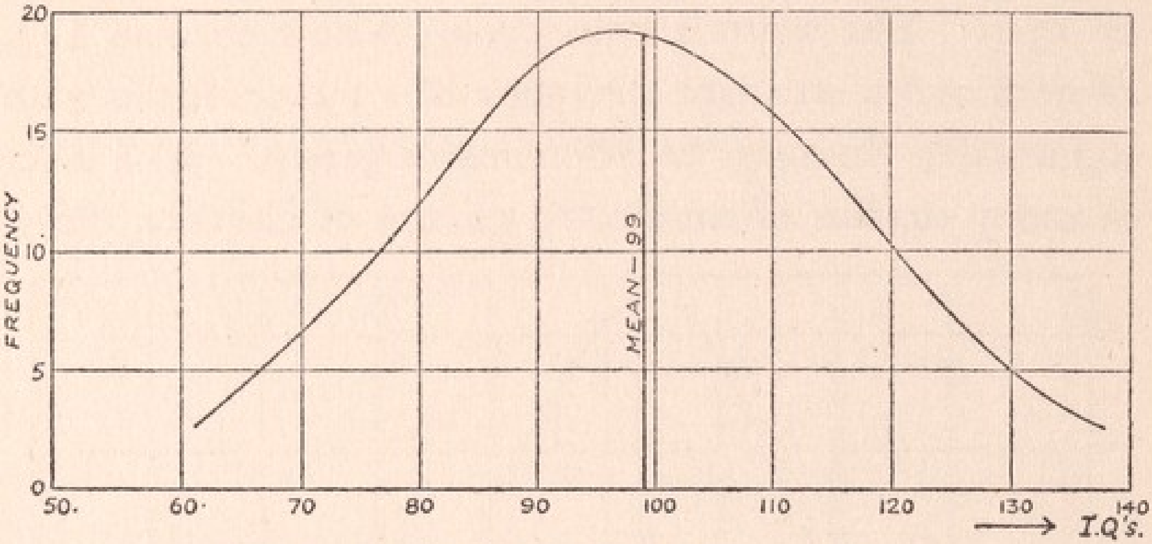

FIG. 6.—Distribution of I.Q.'s of Identical Twins.

similarity, into an identical and a fraternal group. Only those pairs of twins showing practically indistinguishable

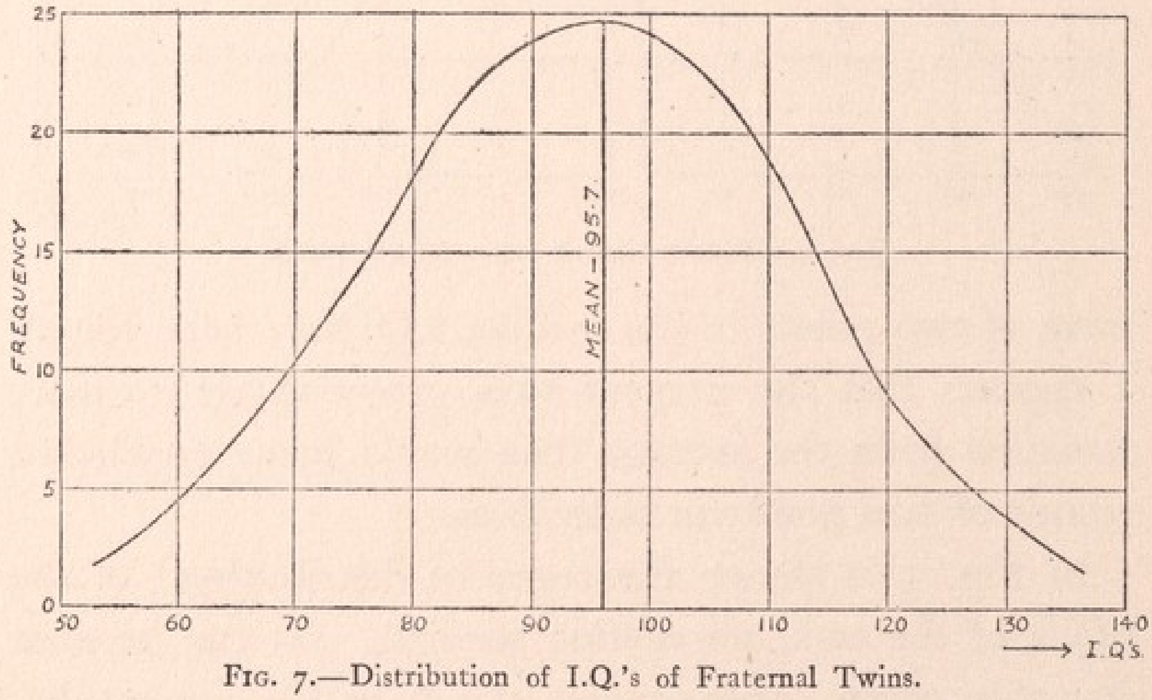

FIG. 7.—Distribution of I.Q.'s of Fraternal Twins.

physical traits, as judged by the teachers of the school and myself, were included in the identical group. While it is not absolutely certain that all pairs included in the identical group had identical heredity, the chances in favour of this being the case are very great. Certainly we would not expect twins having no closer hereditary relationship than brothers and sisters to be identical replicas of each other, but we would expect those having the same heredity to be so. By examining Figs. 6 and 7 it can be seen that separating the twins into two such groups, as identical and fraternal (using "identical" in the sense of physical identity only), does not give distorted frequency curves, but curves very similar to the normal curve of frequency.

Table XI shows the means and standard deviations of the I.Q.'s of the various twin groups.

TABLE XI.

I.Q.'s of Various Twin Groups.

Group.	No. of pairs.	Mean.	S.D.
All twin pairs	102	97·2	13·5
Like-sex pairs	76	95·7	13·6
Unlike-sex pairs	26	98·6	12·9
Fraternal pairs	57	95·7	12·7
Identical pairs	45	99·0	14·3

Consideration of the above table reveals the fact that from the standpoint of intelligence the twin group as a whole approximates very closely to that of a normal unselected group of children, although they are slightly below the average.

2. *Educational Quotients.*

The distribution of the E.Q.'s for all the twins is given in Table XII.

TABLE XII.

Distribution of E.Q.'s of All Twins.

E.Q.	Frequency.
65– 69	3
70– 74	2
75– 79	6
80– 84	11
85– 89	19
90– 94	39
95– 99	35
100–104	25
105–109	24
110–114	13
115–119	8
120–124	0
125–129	2
130–134	1
	N = 188
Median	97·0
Mean	97·6
S.D.	11·24

The data in this table are also given in the form of a curve in Fig. 8.

Table XIII shows the medians and standard deviations of the E.Q.'s for certain twin groups.

TABLE XIII.

E.Q.'s of Various Twin Groups.

Group.	No. of pairs.	Mean.	S.D.
All twin pairs	94	97·6	11·24
Fraternal pairs	52	96·6	11·15
Identical pairs	42	98·7	11·35

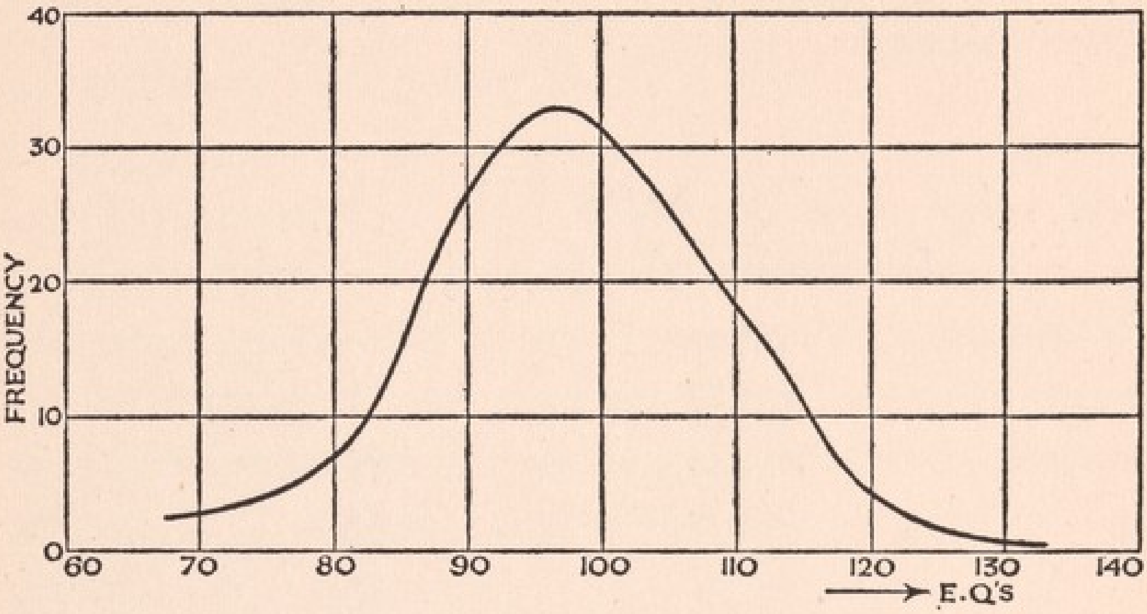

FIG. 8.—Distribution of E.Q.'s of All Twins.

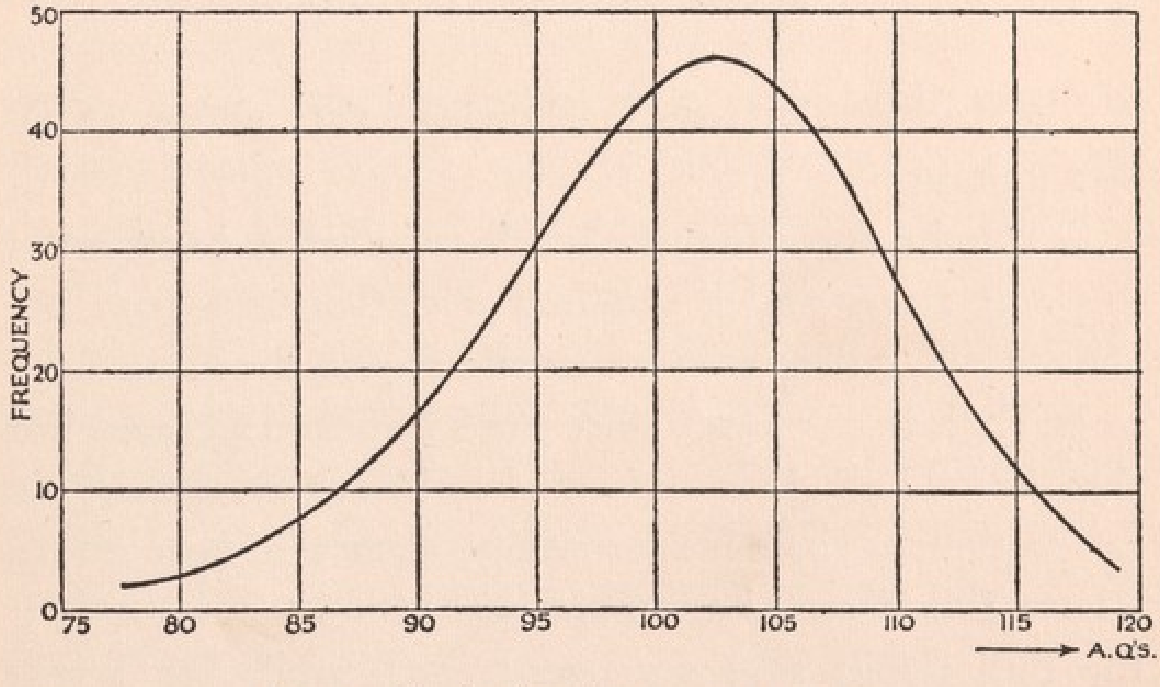

FIG. 9.—Distribution of A.Q.'s of All Twins.

3. *Achievement Quotients.*

In Table XIV is given the distribution of the A.Q.'s for all the twins.

TABLE XIV.

Distribution of A.Q.'s of All Twins.

A.Q.	Frequency.
75– 79	2
80– 84	1
85– 89	13
90– 94	19
95– 99	38
100–104	57
105–109	44
110–114	11
115–119	3
	N = 188
Median	101·8
Mean	101·1
S.D.	8·10

Fig. 9 is the curve showing the above A.Q. distribution.

It is to be noted that the whole twin group had a mean A.Q. of 101·1 and a standard deviation of 8·10. As the mean I.Q. was 97·2 we should expect the mean A.Q. to be slightly over 100, since pupils whose I.Q.'s are less than normal are generally found to be achieving more, in proportion to their innate ability, than are those pupils whose I.Q.'s are above normal. In other words, it is the dull pupils who are over-taught, while the bright pupils are under-taught. If all pupils comprising a given group are being taught to their normal capacity, then the average A.Q. for the group will be 100.

4. *Arithmetic and Spelling Data.*

The arithmetic and spelling scores were not changed into educational ages, since it was simpler to leave them as raw T scores and compare the resemblances between the various groups by a statistical procedure explained in the next chapter. As the members of the twin group were distributed throughout the grades of the elementary school, it is useless to give the mean scores of the group.

B. Orphan Data.

Owing to the modern tendency of Homes and orphanages to place their inmates in foster homes as soon as possible, it was only feasible to obtain 29 children who had spent at least three years in an orphanage. The proportion of a child's life spent in the orphanage varied from 25 per cent. to about 90 per cent. Owing to the small number of children tested, it is impossible to place any great reliance on the results. Nevertheless, the direction in which these results point is well worth considering.

We shall give in the following tables the distributions of the I.Q.'s, E.Q.'s, and A.Q.'s obtained for the orphan group. No curves will be shown, as the number of individuals is so few.

Table XV.

Distribution of I.Q.'s of Orphans.

I.Q.	Frequency.
70– 74	1
75– 79	3
80– 84	4
85– 89	4
90– 94	5
95– 99	7
100–104	3
105–109	1
110–114	0
115–119	1
120–129	1
	N = 30
Mean	92·6
Median	93·0
S.D.	9·15

Table XVI.

Distribution of E.Q.'s of Orphans.

E.Q.	Frequency.
70– 74	1
75– 79	0
80– 84	7
85– 89	4
90– 94	9
95– 99	5
100–104	1
105–109	0
110–114	2
115–119	1
	N = 30
Mean	92·4
Median	91·7

TABLE XVII.

Distribution of A.Q.'s of Orphans.

A.Q.	Frequency.
80– 84	1
85– 89	0
90– 94	2
95– 99	11
100–104	10
105–109	5
110–114	1
	N = 30
Mean	102·1
Median	100·5

From these results it can be seen that these children were of lower intelligence than the twins. Since the parents of children who are found in orphanages and similar institutions are generally of a shiftless, improvident and mal-adjusted type, we should expect the intelligence of their offspring to be lower than that of the generality of the population.[1]

[1] For further information concerning the intelligence of the offspring of the various occupational groups into which the population at large may be divided, see Sandiford, P., "Paternal Occupations and Intelligence of Offspring," *School and Society*, Vol. XXIII, No. 578, pp. 117–19.

CHAPTER VI

STATISTICAL TREATMENT OF THE DATA

The methods selected for working up the data acquired from the administration of the tests were those of "mean differences" and "coefficients of correlation."

1. The method of mean differences is very simple to apply, and the results obtained from it are easily interpreted by non-mathematical people. The procedure is to compute the amount of difference between each pair, sum the differences and divide the sum by the number of cases. This is merely finding the average of the differences. By comparing the average differences found for the various groups that are being studied, it is possible to get some idea as to how the degree of resemblance found in one group is related to that found in another group. This method, however, is very crude, since no account is taken of the variability of the scores, and the effect of age on the scores cannot be eliminated.

2. The best method of computing the resemblance is the Pearson coefficient of correlation (r). It is usually calculated by means of the product-moment formula, $r = \frac{\Sigma xy}{\Sigma x^2 \Sigma y^2}$, in which x is the deviation of a measure from the mean of the first series, and y is the deviation of a measure from the mean of the second series.

Unfortunately, in the case of like-sex twins, where it is desired to correlate the I.Q. of one twin with its mate, there is no way to determine which I.Q. should be considered as the *x*-variable and which as the *y*-variable. They are interchangeable. Correlations are generally calculated between different traits in the same individuals, such as height and weight. But in the present study it is

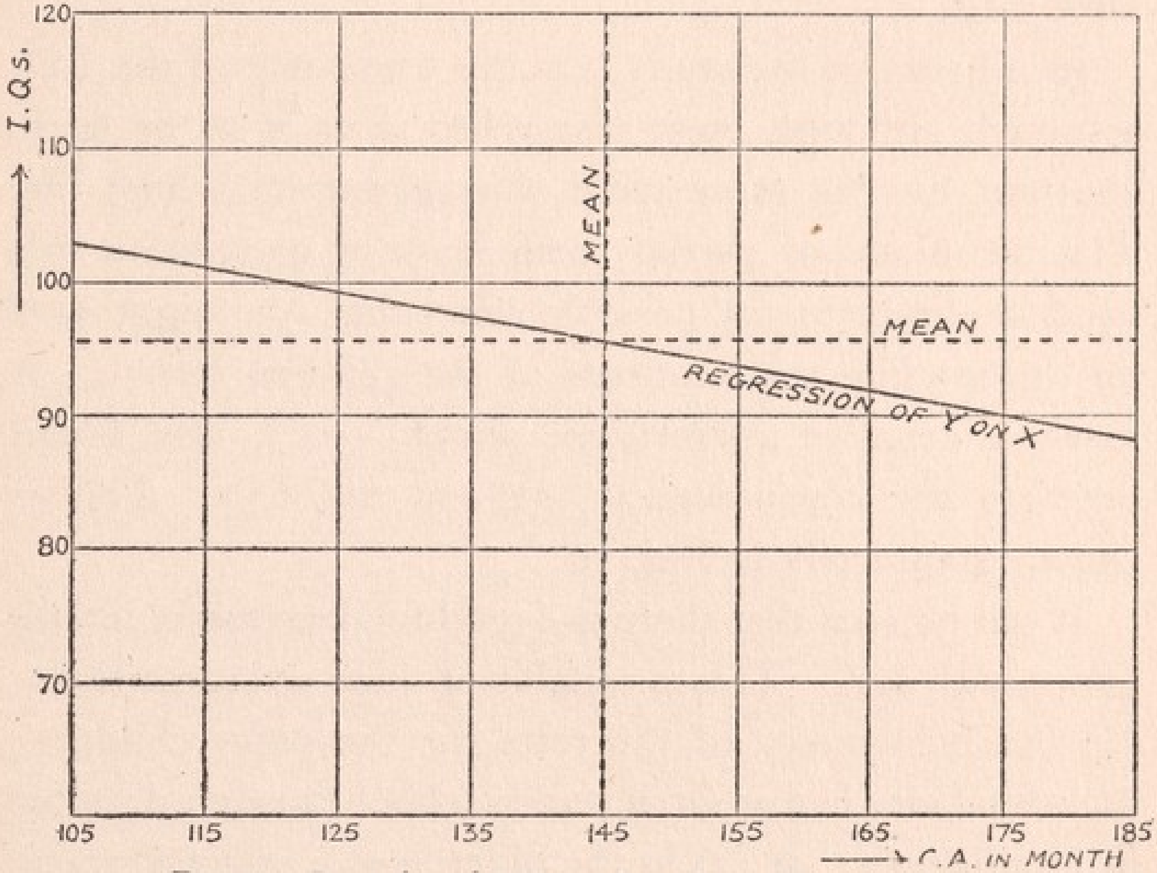

FIG. 10.—Regression of I.Q. on Age of 114 Fraternal Twins.

desired to compute the correlation between the abilities of the members of the twin pairs in one trait, *e.g.* intelligence. It can be shown that spurious correlations will be obtained if numbers are drawn in pairs by chance, and the smaller is always considered as the *x*-variable and the larger as the *y*-variable. In fact the correlation obtained depends directly on the manner in which the *x*- and *y*-variables are chosen.

To overcome this difficulty, the Otis difference formula $r = 1 - \frac{1}{2}\left(\frac{\sigma d^2}{\sigma y^2}\right)$ was used, where σd is the standard deviation of the differences between the scores of each twin pair for the trait measured, and σy is the standard deviation of the scores of all children in general for the same trait.

In no part of the study was the constancy of the I.Q. assumed, although most researches show it to be fairly constant for the same child throughout its school life. The technique of partial coefficients of correlation was used to eliminate any possible effect that age might have on the intelligence quotients of the children tested. A marked negative correlation, about −·27, was found between the chronological age and the I.Q. This is shown graphically in Fig. 10.

It can be seen that there is a gradual decrease in intelligence with age. This is capable of three interpretations: (1) the inadequacy of the tests for the older children; (2) attendance in a modern public school causes a decrease in intelligence; or (3) in the older ages a selected group of children was obtained, the brightest children having passed on to high school. Since the effect of this negative correlation was eliminated in the present study, it was not necessary to determine which of the above three causes was operating. The effect of age on the educational and achievement quotients was similarly disposed of.

In the arithmetic and spelling results the T scores were directly correlated. The correlation between ages and scores was then found, and this effect of age on the scores eliminated, the final correlation found being entirely due to the resemblance among the individuals in either arithmetic or spelling, as the case might be.

It has been shown that the extent of the range of a distribution from which the coefficient of correlation is calculated greatly affects the magnitude of the coefficient. Increase in range generally tends to increase the size of the coefficient, and vice versa. Obviously, then, it is impossible to compare directly one coefficient of correlation with another unless the variability of the data from which each is calculated is identical.

To overcome this difficulty the standard error of estimate ($\sigma\sqrt{1-r^2}$) was calculated for each group for which correlation coefficients were obtained. As can be seen by examining the formula, both the correlation and the standard deviation are taken into consideration. Kelley[1] calls $\sqrt{1-r^2}$ the coefficient of alienation. It may vary from 0 to 1, 0 being perfect correlation and 1 being no correlation at all. It is thus seen to be practically the inverse of the Pearson r and is calculated directly from it. To get the standard error of estimate this coefficient of alienation is simply multiplied by the standard deviation (σ) for the group under consideration. A composite measure is therefore obtained, based directly on the coefficient of correlation and the standard deviation of the group. The smaller this standard error of estimate is, the greater is the resemblance among the individuals comprising the group.

[1] Kelley, T. L., *Statistical Method*, 1924.

CHAPTER VII

THE EFFECT OF ENVIRONMENT

1. *Resemblances of Younger* v. *Older Twins.*

Galton noted (1883) that twins which were reported as being markedly similar in infancy remained so throughout life, even after they had moved to different environments. Twins distinctly dissimilar in infancy, although treated exactly alike until the time of leaving home, remained unlike. Being based on verbal reports, Galton's results cannot be objectively stated. But Thorndike and later students were able to do this. Thorndike (1905) found an average correlation of ·83 for younger twins (9–11 years) and ·70 for older twins (12–14 years). In all Merriman's results (1924) except the teacher ratings, younger twins were found to be more alike than older twins. The Stanford-Binet results, which are his most reliable ones, show a correlation of ·81 for younger twins (5–9 years) and ·76 for older twins (10–16 years). Lauterbach (1925) found an average correlation of ·54 for younger twins ($7\frac{1}{2}$–13 years) and ·55 for older twins (13–20 years) in all the traits which he measured. For intelligence the correlation for younger twins was ·64 and for older ones ·73. His evidence is somewhat conflicting. This is due partly to his neglect of the effect of the variability of his groups on his correlation coefficients and partly to the unreliability of standardised intelligence tests for ages above 14 years. However, all previous experimenters have neglected the variability of their groups, and all, except Lauterbach, have failed to eliminate the effect of age on their coefficients of correlation.

In Table XVIII are given the correlations found for younger and older twins in the present study, both in traits not subject to school training, such as general intelligence, and in traits much subject to school training, such as reading, arithmetic, history, etc. Before the effect of age on the correlations could be eliminated, the correlations between age and the various traits had to be calculated. The following results were obtained:

Chronological age and I.Q., $r = -\cdot 27$.
" " E.Q., $r = -\cdot 49$.
" " A.Q., $r = -\cdot 044$.
" " Arithmetic scores, $r = \cdot 67$.
" " Spelling scores, $r = \cdot 54$.

In the cases of the Stanford Achievement A.Q.'s, Arithmetic scores, and Spelling scores, we note that the younger twins are more alike than the older ones, whether measured by the coefficient of correlation or the standard error of estimate. It must be remembered that the lower the standard of estimate the greater is the resemblance shown. Turning now to the resemblances in intelligence as measured by I.Q.'s, if coefficients of correlations are considered, it is seen that the older twins appear to be slightly more alike. Using the more valid method of

Table XVIII.

Younger Twins (*about* 45 *pairs*) versus *Older Twins* (*about* 50 *pairs*).

Trait.	Twins 8–11 years.			Twins 12–15 years.		
	Raw *r*.	*r* for constant age.	Standard error of estimate.	Raw *r*.	*r* for constant age.	Standard error of estimate.
General intelligence I.Q.'s	·73	·71 ± ·047	8·09	·78	·77 ± ·038	9·16
Stanford Achievement E.Q.'s	·73	·64 ± ·060	8·13	·90	·87 ± ·023	5·35
Stanford Achievement A.Q.'s	·82	·82 ± ·033	3·95	·72	·72 ± ·046	5·10
Arithmetic . . .	·94	·89 ± ·022	2·70	·85	·73 ± ·045	4·00
Spelling	·89	·85 ± ·029	4·18	·89	·85 ± ·026	4·41
Average		·782	5·41		·788	5·60

comparison (the standard error of estimate), this increase in resemblance is seen to be a spurious one, for younger twins are really more alike. The E.Q.'s from the Stanford Achievement show greater resemblances among older twins.

We can, however, determine whether the difference found between coefficients of correlation is a real difference or not by finding the probable error of the difference. The probable error of the difference between two coefficients is found by the formula

$$\text{P.E.}_{\text{Diff. between two coeffs.}} = \sqrt{\text{P.E.}^2_{\text{one coeff.}} + \text{P.E.}^2_{\text{other coeff.}}}$$

If we take the I.Q.'s, then for the younger twins

$r = \cdot 71 \pm \cdot 047$, and for the older twins $r = \cdot 77 \pm \cdot 038$. Then P.E. of the difference is $\sqrt{\cdot 047^2 \pm \cdot 038^2} = \cdot 0604$.

We see, therefore, that the difference between the two coefficients, ·06, is just equal to the probable error of the difference between them. This means that there is a one-to-one chance that the difference found between the coefficients for the I.Q.'s of younger and older twins is entirely accidental. No significance can thus be attached to this difference. It was noted above that if the standard errors of estimate for the I.Q.'s of the younger and older twins are compared, the younger twins resemble each other more than the older ones.

The difference between the coefficients for the E.Q.'s is ·23. The probable error of this difference is ·064, which is about $3\frac{1}{2}$ times the difference found between the coefficients. It would appear that there is a greater resemblance among the older twins when the resemblances are measured by E.Q.'s. This, however, may be explained by the inclusion of a pair of twins in the younger group, one twin of this pair being feeble-minded and in an auxiliary class, while the other twin was quite normal. Since educational quotients depend very greatly on what has been learned in school, a child in an auxiliary class will rate exceedingly low, as he has learned very little of those things that are measured by an educational test. This pair of twins had a great difference in their E.Q.'s. If they had been left out, the coefficient of correlation for younger twins would have been ·76 and the difference then found between the coefficients for younger and older twins would not have been significant.

A study of the average coefficients, when all the traits are considered together, shows that the average coefficients for younger and older twins are almost precisely the same. If standard errors of estimate are considered, then the average standard error of estimate for the younger twins is slightly smaller than that for the older twins. This means that younger twins have a slightly greater degree of resemblance than older twins.

The evidence obtained from this study of younger and older twins can be said to indicate that older twins are certainly no more alike than younger twins. If similarity of training has any appreciable effect in causing similarity of resemblance, then the older twins should be more alike than younger twins. Or, in other words, if mental resemblances are moulded during the "plastic years of childhood," twins should become more alike the longer they are trained together. The results of this study give no evidence for this belief. Heredity accounts easily for the fact that older twins do not become more alike; they are developing along predestined lines, in accordance with their inborn nature and with little regard to the identity of their training. The facts here brought to light cannot be made to conform to the theory that mental likenesses or differences are solely the products of training.

2. *Resemblances in Traits not Subject to Training and in Traits much Subject to Training.*

Thorndike (1905) noted that in traits most subject to training a higher degree of resemblance was found among his twins than in traits least subject to training. But less resemblance was found in traits only moderately subject to training than in those not subject to training. The evidence was conflicting.

Lauterbach (1925) was the only other worker to measure the resemblances of twins in trained abilities. His results are also somewhat confusing, although he says " there is no definite tendency among twins towards greater similarity in acquired traits than in native ability."

The results obtained in the present study are given in Table XIX.

TABLE XIX.

Resemblances of All Twin Pairs in Native and Acquired Traits.

(Correlations are for Constant Age.)

1. E.Q.'s, Stanford Achievement . .	$r =$ ·76 ± ·029 with 94 pairs.
I.Q.'s (general intelligence) . .	$r =$ ·75 ± ·029 with 102 pairs.
Difference . .	= ·01 ± ·041
2. A.Q.'s, Stanford Achievement .	$r =$ ·83 ± ·021 with 94 pairs.
I.Q.'s	$r =$ ·75 ± ·029 with 102 pairs.
Difference . .	= ·08 ± ·036
3. Arithmetic scores	$r =$ ·78 ± ·028 with 88 pairs.
I.Q.'s	$r =$ ·75 ± ·029 with 102 pairs.
Difference . .	= ·03 ± ·040
4. Spelling scores	$r =$ ·85 ± ·019 with 92 pairs.
I.Q.'s	$r =$ ·75 ± ·029 with 102 pairs.
Difference . .	= ·10 ± ·035

Whether each difference found between the coefficients of correlation is a real one or is merely due to the errors of measurement is shown by the probable error of the difference. In none of the differences found between the resemblance in general intelligence and the resemblance in trained abilities (whether measured by educational quotients, achievement quotients, or scores in spelling and arithmetic) is the difference greater than three times the P.E. of the difference. The differences found between the educational quotients and the intelligence quotients and between the arithmetic scores and the intelligence quotients are, in fact, less than their probable errors, that is, the chances are less than one-to-one that they are real differences at all. In the cases of the differences between the achievement quotients and intelligence quotients and between the spelling scores and the intelligence quotients, the differences are $2\frac{1}{5}$ and $2\frac{4}{5}$ times their probable errors respectively. From these data we are forced to conclude that twins are no more alike in those traits in which they have received much training in school (reading, arithmetic, spelling, literature, etc.) than they are in general intelligence, a trait which is supposedly not directly affected by schooling.

The Effect of the Environment in Causing Resemblances.

Since a resemblance of ·75 has been found for general intelligence and a resemblance varying from ·75 to ·85 for school subjects, it is necessary to determine the cause of this resemblance. As we have seen, there is no significant difference in the amount of resemblance among twins in traits on which the school directly concentrates its efforts and in a trait which is only indirectly affected by the school. Also, in all traits measured older twins are no more alike than younger twins, although the moulding force of the school had been longer exerted on the older group during what is believed to be a period of plasticity. These facts support the theory that heredity and not environment is the cause of such resemblances as have been found. Yet it may be argued that all that has been proved is the relative impotence of the environment between the ages of 8 and 15 years to cause the resemblances found. The real cause of similarity may be due to the similarities of the environments *in utero* and the years of early childhood. But the fact of the equality of resemblance of offspring in both paternal and maternal traits is in contravention to any preponderant effect of the mother on the child while *in utero*. Although the sperm and the ovum are themselves very unequal in size, the chromosomes of the two germ cells are of the same size and number. This equality in chromosomal contribution clearly shows the method adopted by Nature to ensure that an equal number of character determinants may be conveyed from each parent, and the reason the environmental effect of the mother on the embryo does not generally have any abnormal effect in causing an excess of maternal resemblance. It is also impossible to conceive that similarity of environment from birth to 8 years of age should have a far greater effect on the ability to add, subtract, read and spell than similarity of environment from 8 to 14 years of age.

But may not this resemblance of about ·75 in the various mental traits measured be due partly to inheritance and partly to environment? In discussing this question, Thorndike (1905) stated: "Assume that the force of the germ natures (heredity) is sufficient to produce an r = ·20 in siblings and ·40 in twins in mental traits. Then we must believe that the likeness in training of a twin pair is enough greater than that in a sib pair, two or three years apart in age, to make the ·40 rise to ·80, whereas the ·20 rises to only ·40 or less. We must then believe either that the similarities in training of twins will raise ·40 to ·80 in physical traits, such as cephalic index, or that the similarities in training of sibs will raise the ·20 only to ·40 or ·50. We must also place the bulk of the influence of this training previous to the tenth year and assume that it is of such a generalised sort as would raise the resemblances in marking A's or words containing *r* and *e* as much as that in multiplication."

CHAPTER VIII

RESEMBLANCE OF TWINS IN GENERAL INTELLIGENCE

THE amount of resemblance of twins in general intelligence was determined by computing the coefficient of correlation between the intelligence quotients of all the members of the various pairs in the group. The intelligence quotient was found for each twin by taking his two mental ages from the two intelligence tests, the National, Form A, and the Multi-mental, and averaging them. This average mental age was then divided by the twin's chronological age to give his intelligence quotient.

The effect of age on the raw coefficient of correlation was eliminated by calculating the correlation between the chronological age and the intelligence quotient. The coefficient of correlation found between these two variables was $-\cdot 27$. The standard error of estimate $(\sigma\sqrt{1-r^2})$ was also calculated for each group of twins, and the mean difference of the intelligence quotients of the various pairs.

In Table XX are given the results for the resemblances of various groups of twins in general intelligence.

All twin pairs have a resemblance represented by a coefficient of correlation of $\cdot 75 \pm \cdot 029$. The resemblances found by other investigators are:

Merriman: $r = \cdot 78$ (Stanford-Binet results).
Lauterbach: $r = \cdot 67$.

TABLE XX.

Resemblance of Twins in General Intelligence.

Group.	No. of pairs.	Raw r.	r for constant age.	Standard deviation. σ.	$\sigma\sqrt{1-r^2}$.	Mean difference in I.Q.'s.
All twin pairs .	102	·76	·75 ± ·029	13·5	8·92	9·65
Unlike-sex pairs .	26	·62	·59 ± ·086	12·9	10·40	12·00
Like-sex pairs .	76	·83	·82 ± ·025	13·6	7·79	8·50
Fraternal pairs .	57	·72	·70 ± ·045	12·65	9·03	11·74
Identical pairs .	45	·91	·90 ± ·019	14·3	6·23	6·23

Merriman's results are too high, owing to the spurious correlation he obtained by neglecting the effect of age on the I.Q. The writer calculated the correlation between age and I.Q. for Merriman's Stanford-Binet data and found $r = -·29$. If this effect of age is eliminated, Merriman's twins have a resemblance represented by $r = ·76$. Lauterbach, while eliminating the effect of age on his coefficients, used only a single group test of intelligence, and hence his resulting I.Q.'s are unreliable. It would appear that the true twin resemblance in general intelligence, based on Merriman's and the present results, is about ·75.

Like-sex Twins v. *Unlike-sex Twins.*

Since all twins having identical heredity, *i.e.* uniovular twins, are of the same sex, we would expect the like-sex twin group to be more alike in intelligence than the unlike-sex group, owing to the original natures of the identical twins being the same. That this is so is borne out by the data in Table XX, from which we find :

Group.	Mean difference in I.Q.'s.	r.	Standard error of estimate.
Like-sex pairs . .	8·5	·82 ± ·025	7·79
Unlike-sex pairs .	12·0	·59 ± ·086	10·40

Whether we measure by mean differences in I.Q.'s, coefficients of correlation or standard errors of estimate, we always find a preponderance of resemblance of the like-sex pairs over the unlike-sex pairs.

Merriman's and Lauterbach's data confirm this. For like-sex pairs Merriman reported an r of ·87 and for the unlike-sex pairs an r of ·50, based on the Stanford-Binet results. Lauterbach found for the I.Q.'s of like-sex pairs an r of ·77, and for unlike-sex pairs an r of ·56, based on either the Terman Group Test or the National Intelligence Test.

The interpretation of these results presents some difficulty. The very fact that a pair of twins are of the same sex results in the members of the pair being treated more alike than the members of an unlike-sex pair would be. But two factors make the possibility of identity of sex as the cause of an increased resemblance extremely doubtful, especially in intellectual traits. The sex factor should have little effect on twins so far as the acquirement of knowledge is concerned. In the previous chapter it was shown that environmental factors had little potency in causing similarity of resemblances in mental traits. The much more probable cause is that in the like-sex group we have quite a number of pairs which are uniovular, while all the unlike-sex pairs are biovular in origin. We have, therefore, a much closer degree of genetic relationship in the former than in the latter group. It is doubtless this closer genetic relationship which has increased the resemblance of the like-sex group over that of the unlike-sex group.

Strong evidence in favour of this last statement is brought to light when we compare the resemblance of the unlike-sex pairs with siblings. The unlike-sex twins are really only siblings who happen to be born at the same time. They originate from the fertilisation of two different ova by two different sperms. Hence, we would expect this type of twins to resemble each other to about the same extent as siblings. The correlation of ·59 ± ·086 for the I.Q.'s of unlike-sex twins obtained in this study is in fairly close agreement with correlations obtained for siblings by various investigators. The following coefficients of correlation for siblings have been obtained.

Pearson (1904) gives ·52 as the general average for all traits which he measured. In an unpublished study by Miss Grace Rensch,[1] Stanford University, is reported an average correlation for I.Q.'s of sibs of ·49 when 847 pairs were studied. For 63 pairs of siblings Madsen [2] obtained a correlation of ·63 ± ·05 based on I.Q.'s. From these and numerous other studies on the same subject we note that sib resemblance is of a degree represented by a correlation of ·50 or thereabouts. Thus, if

[1] Quoted from Merriman, C., "The Intellectual Resemblance of Twins," *Psychological Review*, 1924, Vol. XXXIII, Monograph 5, pp. 1–58.

[2] Madsen, I. N., "Some Results with the Stanford Revision of the Binet-Simon Tests," *School and Society*, May 10, 1924, p. 559.

we compare Merriman's correlation of ·50, Lauterbach's of ·56, and the writer's of ·59, all obtained for unlike-sex pairs of twins, with the generally found correlation of approximately ·50 for siblings, we must conclude that unlike-sex pairs of twins do resemble each other to about the same extent as siblings.

Physically Identical Twins v. *Fraternal Twins*.

It was impossible to obtain the embryological evidence necessary to prove whether twins were uniovular in origin or not. The only feasible method was to divide all the twins into two groups based on physical likeness. Those twins which were physical duplicates of each other were called identical twins, while those which were not were called fraternal twins. All the unlike-sex pairs could be put at once into the fraternal group, as they are all biovular twins. The difficulty was to separate the like-sex twins into the two groups. However, it is highly probable that the great majority of twins included in the physically identical group are uniovular twins, while those which were dissimilar in physical appearance are biovular twins.

If we again examine Table XX it is remarkable to note how great is the disparity in resemblance between the identical and fraternal groups.

Group.	Mean difference in I.Q.'s.	*r*.	Standard error of estimate.
Identical pairs .	6·23	·90 ± ·019	6·23
Fraternal pairs .	11·74	·70 ± ·045	9·03

The coefficient of correlation of ·90 for the identical twins is so high that it is practically as great as Newman obtained for the physical traits of the uniovular quadruplets of the nine-banded armadillo or as is found between the resemblances of the right and left halves of a single individual. On the other hand, the correlation of ·70 for fraternal twins is less than that of all twins in general. In answer to the argument that this low correlation for the fraternal pairs is due to a great number of unlike-sex pairs being included in the fraternal group, it may be pointed out that of the 57 pairs comprising the total fraternal group, 31 pairs are of like sex, while only 26 pairs are of unlike sex.

The significance of the gradual increase in resemblance in intelligence as we pass from unlike-sex pairs, which have the least degree of common heredity among the groups considered, to the physically identical pairs, which most probably have the greatest degree of common heredity, will be shown in the last chapter.

CHAPTER IX

RESEMBLANCE OF ORPHAN CHILDREN IN GENERAL INTELLIGENCE AND ACHIEVEMENT

If the cause, or partial cause, of the similarity found between twins or siblings is due to similarity of environment and training, we should expect to find that children who have been reared for a considerable period of their earlier lives, especially during the " plastic " period of early childhood, in a very nearly constant environment would show a fair degree of resemblance in various mental traits when paired with each other at random.

In order to verify or disprove this hypothesis, the same tests that were given to the twins, as reported in the preceding portion of this study, were given to a group of orphan children who had been reared together for 25 to 75 per cent. of their lives. As the number of such children which could be obtained for this purpose was only 29, the results obtained are not very reliable. Nevertheless, the significance of the direction in which they point is worthy of serious consideration.

All the coefficients given in this chapter are Pearson coefficients of correlation. These were obtained by first calculating the Spearman R for the group and then transmuting this R into the Pearson *r*. This Pearson *r* was finally freed from the effect of age.

Two methods of pairing the orphans were used. The first method was to pair an orphan with another who was nearest to him in chronological age. The second method was to pair the orphans with each other at random. The following tables give the results which were obtained when these two methods were used. No probable errors are given, as the cases are too few to allow the P.E. formula $\left(\text{P.E.}_r = \cdot 67 \frac{1 - r^2}{\sqrt{N}}\right)$ to be used.

Table XXI.

Orphans Paired at Random: 15 Pairs.

Trait.	Raw r.	Correlation between age and trait.	r for constant age.
I.Q.'s	−·49	−·18	−·54
E.Q.'s	−·19	−·62	−·79
A.Q.'s	−·54	−·38	−·79
Arithmetic . . .	·14	·58	−·30
Spelling . . .	·08	·61	−·46
		Average . .	−·58

In Table XXI we see that not only is there no resemblance when orphans are paired at random for intellectual traits, but there is a fair degree of inverse correlation. When the orphans are paired to the nearest age, we note in Table XXII that there is a slight degree of resemblance in the case of the I.Q.'s and arithmetic scores, while in the A.Q.'s and spelling scores there is a somewhat more marked correlation, although it is still low. The correlation found for the E.Q.'s is practically zero. The average correlation obtained when orphans are paired to the nearest age is ·24, which is practically none at all. The correlations in Table XXII are all so small and their probable errors so great, owing to the fewness of the cases, that they may be entirely due to chance errors of measurement. The correlations given in Table XXI, where random pairing is used, are larger and therefore more significant, but it is noteworthy that they are all negative, indicating complete lack of similarity in the traits in which the comparisons are made.

TABLE XXII.

Orphans Paired to Nearest Age: 15 Pairs.

Trait.	Raw *r*.	Correlation between age and trait.	*r* for constant age.
I.Q.'s	·16	—·18	·13
E.Q.'s	·34	—·62	—·07
A.Q.'s	·54	—·38	·47
Arithmetic . . .	·46	·58	·18
Spelling . . .	·59	·61	·35
		Average . .	·24

Hildreth [1] reported a correlation of ·0047 ± ·07 for the random pairing of the I.Q.'s (Stanford-Binet) of 100 pairs of orphans reared for 25 to 100 per cent. of their lives in the Hebrew Orphan Asylum of New York City.

[1] Hildreth, G. H., *The Resemblance of Siblings in Intelligence and Achievement*, Columbia University Contributions to Education, No. 186, 1925.

This correlation is of the same degree of magnitude as that obtained when unrelated children, who have been reared apart, are paired at random for I.Q.'s.

It appears from the facts given here that no evidence has been found to substantiate the belief that unrelated children, when reared in the same environment, will show any greater resemblances when paired together at random than will unrelated children, who have been reared apart. These results are in agreement with the conclusions which were drawn in Chapter VII as to the impotency of the environment in causing any appreciable effect on the resemblances found among twins.

CHAPTER X

THE INHERITANCE OF INTELLIGENCE

It has been found in this study that 102 pairs of twins, selected at random, have a degree of resemblance in general intelligence represented by a coefficient of correlation of ·75 ± ·029. If the total twin group is subdivided (1) on the basis of sex and (2) on the basis of physical identity or non-identity, we get correlations varying from a minimum of ·59 ± ·086 in the case of the unlike-sex pairs to a maximum of ·90 ± ·019 in the case of the physically identical twins. What is the cause (or causes) of these high correlations? Are they attributable to heredity, environment, or to both?

The assumption that environmental factors are adequate to account for these resemblances is disproved by the following facts:

(1) There is no significant difference in the amount of resemblance between younger and older twins. The standard errors of estimate, based on the tests of general intelligence, are 8·09 and 9·16 for younger and older twins respectively. If anything, the younger twins are more alike than the older ones. If similarity of environment is causing the resemblance found in intelligence, we should expect to find the older twins becoming more alike,

at least up to the time when they leave home. The facts presented here do not bear this out.

(2) The twins are no more alike in those traits upon which the school has concentrated its training than in general intelligence, which is not directly trained in school. Surely, if children are so susceptible to the moulding effect of environment, we should expect them to be very much alike in acquired traits, such as spelling, reading, arithmetic, etc., in which they have been educated or trained together. Especially should this be true in the case of twins who start school at the same time, are kept in the same classes with the same teachers, probably study together at home and receive, in general, identical scholastic treatment in the various school subjects. Yet we find them no more alike in these school subjects than they are in general intelligence. And the school does not consciously strive to train children to do well on intelligence tests!

(3) It is appropriate to introduce here a remarkable condition found among those twins, not physical duplicates of each other, which the writer placed in the fraternal group. It was found that although these twins started school life together, certain pairs soon had one member of the pair a grade or more ahead of the other. Of the total of 57 pairs placed in the fraternal group, it was discovered that there were three pairs in which one twin was so dull mentally as to necessitate his transference to an auxiliary class, while the other twin was normal and progressed at the normal rate in school. A large number of the remaining fraternal twins had the members of

their respective pairs separated by a varying number of school grades. The twins comprising the physically identical group were not all in the same grades as their mates, but the degree of separation which was found among them was much less than in the fraternal group. For the 57 pairs of fraternal twins an average difference of ·83 of a grade was found, while for the 45 pairs in the identical group there was only an average difference of ·31 of a grade between them.

Does environment or heredity more plausibly account for the fact that fraternal twins diverge more in their school work than do identical twins? Since they began school life together and have been given the same quantity and kind of training, it is difficult to understand, providing one believes in the theory that similar training will produce similar results, why the members of the fraternal pairs have become separated, on the average, from each other by 270 per cent. of the average difference separating the identical pairs.

On the other hand, heredity will easily explain these facts. The fraternal twins start out with different heredities, while the identical twins are, as we have seen, really halves of the same hereditary material. Thus the same environment is really playing on twins with different heredities in one case, and with similar heredities in the other. We should, therefore, expect to find that the resulting products will differ from each other much more in the fraternal than in the identical pairs. There is certainly no levelling effect due to similar environment taking place here. How long are we to be asked to believe on blind faith that the child is putty which the educator, depending on his skill, can make into either a mediocrity or a genius? It would be interesting to know what reply the environmentalist would make if he were asked by the parent of twins why one of them was two grades ahead of his mate when both had undergone exactly the same amount of educational training.

(4) Another factor tending to strengthen the argument that environment is inadequate to account for the high degree of mental resemblance in twins is the data derived from studies of orphan children who have been reared together for a considerable part of their lives. Not one tittle of evidence has been adduced by anyone to show that these unrelated children are any more alike in mental ability than are unrelated children who have been reared apart and paired together at random.

Adequacy of the Principle of Homology to Account for Twin Resemblance.

It will be recalled that the principle of homology maintains that closeness of resemblance is in proportion to closeness of kinship. Biologists generally consider this law as involving physical structure only. But since it is noted that throughout the whole scale of animal life we obtain an increasing degree and complexity of behaviour with increase in degree and complexity of the nervous system, we may, therefore, state that behaviour is a function of the central nervous system and, as such, is dependent on neurological structure. Now neurological structure is certainly a physical entity and follows the law of homology. Hence we would, *a priori*, expect phenomena due directly to the action of the nervous system to obey this general law also. That they do, we shall show from the results obtained in this study along with those from certain previous ones.

Twins v. *Siblings*, *Cousins*, *etc*.

The amount of twin resemblance for various mental traits is approximately represented by a coefficient of correlation of ·75 when twins in general are considered. Sibling resemblance is usually found by most investigators to be about ·50. Schuster and Elderton [1] give the degree of resemblance between father and son as ·31, and that between cousins as ·27. Biologically, father and son may be looked upon as half-brothers, that is, offshoots of the same strain of paternal germ plasm but different strains of maternal germ plasm. We should, therefore, expect the resemblances between them to be smaller than that of siblings, but greater than that of cousins.

We noted that the unlike-sex twin pairs in the present study had a resemblance approximately equal to that of siblings, being $\cdot 59 \pm \cdot 086$. Like-sex twins, which included a large number of uniovular pairs, had a resemblance of $\cdot 82 \pm \cdot 025$. For the physically identical twins we found a correlation of $\cdot 90 \pm \cdot 019$, and for the non-identical or fraternal twins a correlation of $\cdot 70 \pm \cdot 045$. Doubtless we have inadvertently included some

[1] Schuster, E., and Elderton, E., *The Inheritance of Ability*, Eugenics Laboratory Memoirs, 1907.

uniovular twins in the fraternal group, which will account for the resemblances of this group being greater than that of the unlike-sex group.

We have now forged a very strong chain of evidence purporting to verify the law of homology in its application to the inheritance of intelligence. The various links in this chain, when the mental resemblances found among the various groups are expressed as coefficients of correlation, are as follows:

Physically identical twins	·90
Like-sex twins	·82
Fraternal twins	·70
Unlike-sex twins	·59
Siblings	·50
Parent-child	·31
Cousins	·27
Grandparent-grandchild	·15
Unrelated children	·00

Bearing in mind the degree of genetic relationship existing between the individuals comprising the above groups, one is forced, literally forced, to draw the conclusion that *the closer the genetic relationship between individuals, the closer is the degree with which they will resemble each other in intelligence.*

Evidence bearing on the Inheritance of Intelligence by a Comparison of Physical v. *Mental Traits.*

Pearson argued for the inheritance of intelligence, since he found the same degree of resemblance in the mental traits of siblings as he found for those physical traits which are not subject to environmental influence. Fisher,[1] using the measurements of cephalic index obtained by Lauterbach in his study of twins, found that the resemblance for the like-sex pairs was ·73 and for the unlike-sex pairs ·54 in cephalic index. For these same twins Lauterbach gave the resemblance in intelligence for the like-sex and unlike-sex pairs as ·77 and ·56 respectively. Pearson's arguments (given in Chapter III) regarding the validity of inferring the inheritance of mental traits when they are found to have the same degree of resemblance as physical traits not subject to environment, are equally applicable here.

Fisher also calculated the resemblances for weight and height of twins, but these will not be discussed, since weight and height are traits which may be seriously affected by environmental factors. But cephalic index (ratio of head width to head length) is probably not susceptible to modification by such factors as food, climate, sleep, etc. Even if it were somewhat modifiable, it is highly improbable that it would be affected by differing factors in the case of twins, at least up to the age of fifteen.

In conclusion it may be said that on the basis of the present study similarity of environment will not account for the resemblance in general intelligence found among twins. Such similarity is directly attributable to the closeness of their hereditary or genetic relationship. Or, in other words, general intelligence is an inherited trait.

[1] Fisher, R. A., "The Resemblance between Twins: a Statistical Examination of Lauterbach's Measurements," *Genetics*, Nov. 1925, Vol. X, No. 6, pp. 569–79.

Vertical and Horizontal Growth in Intelligence.

Two concepts which are of help in evaluating an individual's total mental ability are the amounts of vertical and horizontal mental growth which he has undergone. Vertical growth in intelligence means the distance up the absolute scale of intelligence which an individual has reached. This level or altitude of intellect is measured by the *difficulty* of the intellectual tasks which can be performed successfully. We cannot say with certainty that one person is necessarily more intelligent than another merely because he knows more things than the latter, but, if he is able to do harder things than another can do, then we would not hesitate to declare him the more intelligent. Obviously a person who has mastered an intellectual task of a given degree of difficulty can successfully continue to master tasks of a similar degree of difficulty. He is then said to be growing horizontally in intelligence. The following diagram will serve to clarify the conceptions of vertical and horizontal growth in intelligence.

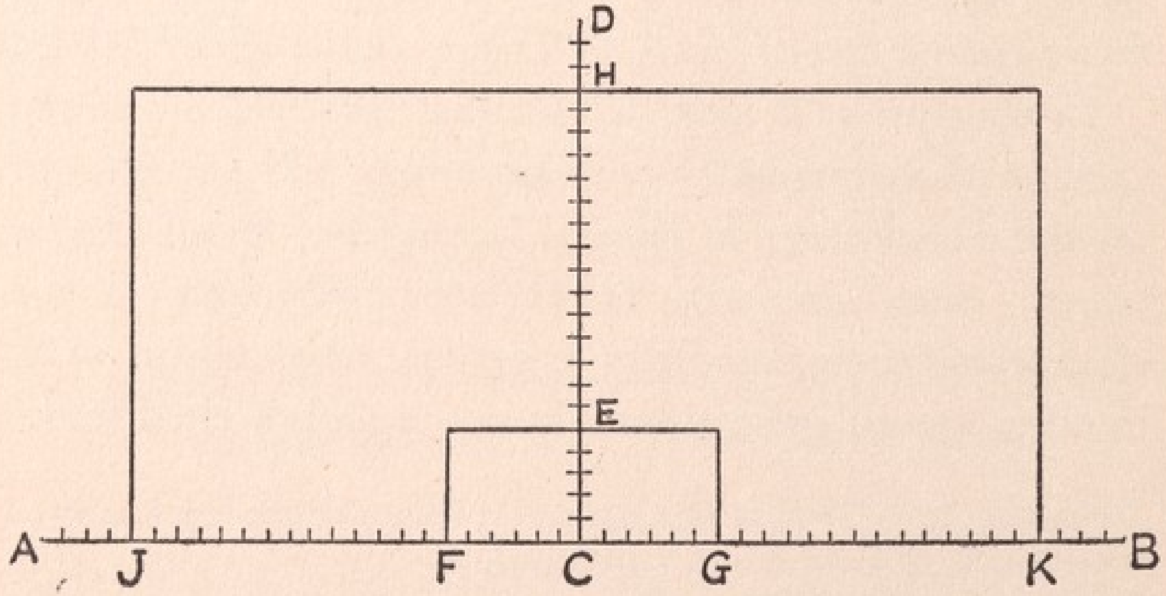

Fig. 11.—Vertical and Horizontal Growth in Intelligence.

AB represents the number of intellectual tasks, while CD represents the difficulty of intellectual tasks, C being the supposedly absolute zero for difficulty, while D is the highest point ever attained by the greatest man of genius, say Aristotle. Now on either side of this line representing the difficulty of mental tasks we can plot the number of tasks that can be done at any given level of intelligence. If E represents the level of difficulty to which a moron is capable of rising, then when he has developed to this point in his vertical growth he can only hope to grow horizontally in intelligence thereafter. That is, he can greatly increase the *number* of tasks which are represented in *difficulty* by a height of E or less, but he cannot acquire the ability to do tasks of a higher degree of difficulty than E. Since height multiplied by width gives area, we may conveniently designate this moron's intellectual area as the height CE × FG.

In contrast with the moron we can compare the area possessed by a type of superior mental ability, the genius. The intellectual tasks which he can accomplish are exceedingly high on the scale of difficulty, that is, he has achieved a high level of growth, represented by CH. The number of tasks of which he will be master will depend on his horizontal growth due to training. Suppose it is represented by JK. Then the area of his intellect, vastly greater than the moron's, is JK × CH. It is to be noted that vertical growth and horizontal growth are usually highly correlated. The extent of information which an individual possesses is generally a good criterion of his intellectual ability.

By our illustration we can also understand why two persons of equal vertical growths in intelligence sometimes exhibit to the world different amounts of intellectual achievement. They are cases of unequal horizontal growth making for different intellectual areas. This horizontal growth may be dependent on other factors not measured by intelligence tests—morality, zeal, and the like—factors obviously important in the consideration of a person's total achievement.

Education must be given chief credit for increase in horizontal growth. While the altitude or vertical growth in intelligence which a person attains is definitely fixed by heredity, his horizontal growth can be prolonged indefinitely by education—either self-education or formal schooling. Since the area of an intellect depends on both its vertical and horizontal factors, and since the school is impotent to increase the former, it should aim at the greatest possible amount of horizontal growth at the highest attainable level.

As a conclusion to this study no words more fitting than those written by Francis Galton sixty years ago can be given. With a prescience that can only be regarded as remarkable, he stated:

" I acknowledge freely the great power of education and social influence in developing the active power of the mind, just as I acknowledge the effect of use in developing the muscles of a blacksmith's arm, and no further. Let the blacksmith labour as he will, he will find there are certain feats beyond his power that are well within the strength of a man of herculean make, even although the latter may have led a sedentary life. . . . In running, rowing, walking and in every other form of physical exertion there is a definite limit to the muscular powers of a man which he cannot by education or exertion surpass. This is precisely analogous to the experience that every student has had of the working of his mental powers. To each of us a limit is set—a limit, as far as one can see at present, due to heredity rather than to opportunity, and to the intelligence of our parents and ancestors rather than to the educational system under which we were reared."

Summary.

1. Twins as a group are very slightly (1–2 per cent.) below the average in general intelligence, but show about the same degree of variability as unselected children.

2. Orphan children are below the average intelligence of unselected children.

3. There is no significant difference in the amount of resemblance in mental traits between younger and older twins.

4. Twins are no more alike in those traits upon which the school has concentrated its training than in general intelligence.

5. Hence, considering arguments 3 and 4, environment is inadequate to account for the mental resemblances of twins.

6. Twins show practically the same degree of resemblance in general intelligence and cephalic index.

7. Like-sex pairs of twins show a greater degree of resemblance in intelligence than unlike-sex pairs.

8. Unlike-sex pairs of twins have approximately the same degree of resemblance in intelligence as siblings.

9. There are two distinct types of twins because:

(*a*) The like-sex group, which must partly consist of a number of uniovular, or identical pairs, shows a higher degree of mental resemblance than the unlike-sex group.

(*b*) Physically identical pairs show a higher degree of mental resemblance than fraternal pairs.

(*c*) The degree of resemblance of sibs in mental traits is nearer to that of the unlike-sex pairs than to that of the like-sex pairs. This bears out the contention that unlike-sex pairs, from the genetic standpoint, are really siblings that are born at the same time.

(*d*) Members of fraternal pairs of twins show, on the whole, greater diversity in school grades than members of physically identical pairs. This latter group is probably composed largely of uniovular pairs.

10. Orphan children, who have been reared together for a considerable portion of their lives, are no more alike than unrelated children paired at random, either in general intelligence or in other intellectual traits.

11. The amount of resemblance in general intelligence among human beings varies from a minimum of $r = 0$, in the case of unrelated individuals, to a maximum of $r = \cdot 90$, in the case of physically identical twins. Intermediate values are found according to the genetic relationship of the individuals. Therefore, we can say, there is an increasing degree of resemblance in general intelligence among human beings with increase in the degree of genetic relationship among them; or, in other words, general intelligence is an inherited trait.

APPENDIX A

EFFECT OF THE INHERITANCE OF INTELLIGENCE ON EDUCATIONAL ADMINISTRATION

SINCE we have seen that the capacity called general intelligence is transmitted as an inherited trait and that the rôle of the environment is developmental and not creative, the only method of providing equal educational opportunities for all is by making our educational methods suit the inborn, but varying, capacities of children. That which a brilliant child of nine or ten years of age is capable of learning is beyond the capacity of a dull child until perhaps he is fifteen years old. It is manifestly unjust and pedagogically unsound to instruct these two children together, although at the same chronological ages both may have attained the same physical maturity.

The basic factor in learning is native intelligence, and the pressing problem now engaging the attention of educational administrators is to devise methods of dealing with large numbers of children so that each individual will be given the special instruction which his native ability demands. This must be accomplished without sacrificing the advantages, both economic and educational, attendant on group instruction.

The most feasible plan so far proposed is that of classifying pupils into fairly homogeneous groups on the basis of *mental* maturity. In classes ungraded from the standpoint of native intelligence, the teacher is forced to adapt his teaching to the average mental level of the class. This results in the dull children being over-taught, while the bright ones are under-taught. These latter can generally finish their assigned work in half the time required by the rest of their class-mates, and if further tasks are not provided for them, they are likely to form indolent and mischievous habits.

To overcome the difficulties arising from classes containing heterogeneous mental ability, certain cities have adopted what is known as the X Y Z plan of grading. This is done by obtaining the mental ages of all the pupils which make up a given grade in a public school. The top 20 per cent. are taken and formed into the X group, or group of superior ability; the middle 60 per cent. form the Y group, which is composed of pupils of average ability; and in the Z group are placed the dullards.

Each group is given a different curriculum. The Y group is taught what is considered to be the appropriate curriculum for the grade; the X group is given an enriched course of study; while the Z group covers less than the average work required for the grade.

Since it is now realised by educators that "you cannot make a silk purse out of a sow's ear," provision must be made for those unfortunate individuals who are found at the lower end of the normal curve of the distribution of intelligence. The only sane policy to adopt is that of segregation of the definitely feeble-minded—those with

I.Q.'s below 70. It is impossible for them to master, with any degree of success, situations requiring the use of abstract reasoning powers. They can be taught by very laborious methods to read, to repeat history, geography, etc. The effort required to enable them to do this is not worth while, since they never really learn, that is, in the sense of acquiring an adequate comprehension of the meaning of words. Effort should be concentrated on the development of such ability as they possess, chiefly along lines involving hand-work, such as farming and the more unskilled branches of the trades.

Public opinion, which has sanctioned the segregation of the feeble-minded children, is now beginning to demand that the talented or gifted child, found at the extreme right of the normal curve of intelligence, shall be adequately looked after and that his great latent abilities shall not be dissipated. If it is worth while to give special attention to the feeble-minded, surely it will repay us a thousand-fold to see that those children who possess the potential ability to become future leaders in affairs of Church, State and commerce shall not suffer through lack of the best training we can give them. All progress in the world is undoubtedly due to a few great men, the Pasteurs, Darwins, Newtons, etc., and the rest of the people have merely been followers in the new realms opened up by these great minds. Admitting that the poorest land, if fertilised, will produce a richer harvest, will not the same material and effort expended on better soil give far greater returns? A nation's gifted children are its most precious possessions, and should be looked after accordingly. It is significant that in our more progressive communities arrangements are now being made to do this.

Children with I.Q.'s of about 130 and above are being put into classes by themselves, where they are allowed to progress in proportion to their native ability. It has been noted that when first segregated they are lazy, since previously they have merely had to loaf along to keep up with their schoolfellows. But if placed in a class for gifted children they must work as hard as normal individuals do, in order to retain their places among their peers. Their curriculum is greatly enriched, but, guided by the principle that the only real education is self-education, either they are largely self-taught or they teach each other. The teacher's function is merely to give assistance when help is needed.

The futility of attempting to evaluate the results of teaching when no consideration is taken of the original nature of the individuals under tuition is apparent when we remember that a teacher cannot create mental ability but can only develop it. Two teachers possessing equal teaching ability and teaching two classes in the same grade will achieve entirely different results at the end of the year, unless the average mental ability of each class has been the same. Franzen's appreciation of this difficulty in measuring the results of teaching led him to invent the achievement quotient (sometimes called the achievement ratio). This quotient is obtained by dividing a child's educational age, obtained by means of a standardised educational test, by his mental age and multiplying by 100.

A child's mental age tells how far his natural growth in intellectual ability has proceeded. If he has been taught up to the limit of his powers, then his educational age will equal his mental age. If his educational ability is below his mental ability, he has not received as much advantage from his schooling as he might have obtained, and vice versa. It is a remarkable fact that when educational quotients are computed for large numbers of pupils, we find that it is the dull children who are accomplishing more in proportion to their native ability than are the brilliant ones. This should give educators serious food for thought, as it appears that their efforts are being concentrated more on the lower half of their intellectual material than on the upper half.

Lest it be thought that environment counts for little or nothing in the production of an individual, we shall briefly describe its rôle. It controls the intellectual and physical growth of an individual, not by creating any potentialities, but by developing those latent powers which will later become apparent in the mature person. The word " education " means a leading out of what is inherently present in man. This describes exactly the function of an ideal environment, providing we control it so as to develop only those qualities which are socially desirable and kill off all others.

Given a certain heredity to work with, it is obviously essential that the best environmental forces should be brought to bear upon it if one wishes to get the best possible finished product. But while a very bad environment may be able to destroy fairly good hereditary potentialities and produce a nonentity, it is quite impossible for the best environment to produce a gifted individual, unless it has good hereditary material to work upon. It seems, therefore, that heredity is the basic factor in the creation of intelligent human beings, but nevertheless it is most important that the best available environmental forces be allowed to develop the potentialities implanted by heredity. Heredity and environment work hand in hand; they are essentially correlatives of each other.

APPENDIX B

ORIGINAL DATA OBTAINED FOR TWINS

Note.—All males designated by "a" or "b"; females by "x" or "y." Each pair of twins is given a number. Thus: 1–xy is a pair of girls; 2–ab is a pair of boys; 46–ax is a boy-girl pair.

Identical Twins.

Pair.	Grade.	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison McCall Spell. T. Score.	B.C. Arith. T. Score.
1–x	8	168	13– 7	16– 0	14–10	106	13– 2	94	89	60	46
1–y	8	168	13– 0	16– 0	14– 6	103	12– 9	91	88	57	54
2–a	6	137	10– 8	11– 6	11– 1	97	10–10	95	98	48	26
2–b	6	137	10– 6	11– 5	11– 0	96	11– 4	99	102	47	33
3–a	7	159	14– 8	16– 0	15– 4	116	15– 4	116	100	45	50
3–b	8	159	14– 2	15– 8	14–11	113	14– 7	110	98	45	51
4–x	3	116	9– 5	10– 1	9– 9	101	9– 4	97	96	38	—
4–y	3	116	10– 0	8– 6	9– 3	96	9– 9	101	105	41	—
5–x	—	124	9– 0	7–11	8– 6	82	9– 0	87	106	36	26
5–y	—	124	9– 7	10–10	10– 3	99	10–10	105	106	48	33
6–x	—	169	9– 4	10– 6	9–11	70	10– 2	72	103	38	35
6–y	—	169	10– 0	10– 8	10– 4	73	10–10	77	105	42	39
7–x	6	170	11– 2	11– 7	11– 5	81	12– 0	85	105	36	42
7–y	5	170	10– 0	11– 7	10–10	76	11– 1	78	102	48	38
8–a	6	160	10– 2	10– 4	10– 3	77	10– 8	80	104	36	38
8–b	6	160	11– 6	10– 8	11– 1	83	11– 5	86	103	43	38
9–x	5	121	11– 4	11– 1	11– 3	112	11– 2	111	99	49	34
9–y	5	121	10–11	11– 1	11– 0	109	11– 2	111	101	47	38
10–a	2	89	9– 4	—	9– 4	126	—	—	—	—	—
10–b	2	89	9– 5	—	9– 5	127	—	—	—	—	—
11–x	8	162	10–11	11–10	11– 4	85	—	—	—	—	—
11–y	8	162	11– 6	12– 1	11– 9	87	—	—	—	—	—
12–a	5	144	10– 4	11– 6	10–11	91	11– 6	96	105	48	41
12–b	6	144	11–10	11– 2	11– 1	93	11– 9	98	106	51	48
13–a	8	159	12– 7	11–11	12– 3	93	12–11	97	105	51	49·5
13–b	8	159	12– 7	12– 6	12– 6	95	13– 5	101	107	53	51
14–x	5	140	10– 4	10– 2	10– 3	88	10–11	94	107	47	37·5
14–y	5	140	10– 6	10– 5	10– 6	90	11– 2	96	107	50	39
15–x	8	149	18– 0	13– 3	15– 8	126	13– 6	109	86	69	46

Identical Twins (continued)

Pair.	Grade.	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison McCall Spell. T. Score.	B.C. Arith. T. Score.
15–y	8	149	13– 2	13– 4	13– 3	107	13– 7	109	102	60	51
16–x	6	164	11– 3	11– 5	11– 4	83	11– 4	83	100	52	38
16–y	6	164	11– 4	11–11	11– 8	85	11– 8	85	100	55	39
17–x	6	143	11– 4	11– 6	11– 5	96	12– 2	102	106	53	39
17–y	6	143	12– 7	13– 3	12–11	108	12– 6	105	97	53	44
18–x	6	132	11– 5	11– 6	11– 6	104	11– 6	105	100	48	38
18–b	6	132	11– 6	11– 6	11– 6	105	11– 6	105	100	51	33
19–x	5	130	10– 1	10– 6	10– 4	95	11– 0	101	107	48	33
19–y	5	130	9– 5	10– 3	9–10	91	10– 8	99	108	40	30·5
20–a	5	144	10– 2	8– 0	9– 1	76	10– 7	88	116	44	31·5
20–b	5	144	10– 2	9– 2	9– 8	81	10– 8	89	109	44	30
21–x	2	101	8– 6	8– 0	8– 3	98	9– 9	116	118	37	30
21–y	2	101	9– 4	8– 0	8– 8	103	9– 9	116	113	39	21·5
22–x	7	155	11– 4	12– 0	11– 8	90	11– 8	90	100	65	44
22–y	7	155	11– 1	11– 8	11– 5	88	11– 8	90	102	60	40
23–a	5	129	10– 7	10– 8	10– 8	99	9– 9	91	92	44	29
23–b	5	129	11– 4	10– 9	11– 1	103	10– 3	95	93	43	31
24–a	8	156	13– 0	11– 0	12– 0	92	11– 5	88	95	65	39
24–b	8	156	13– 0	12– 9	12–11	99	12– 0	92	93	67	44·5
25–x	6	170	13– 2	14– 6	13–10	98	12– 6	88	90	57	43
25–y	7	170	16– 5	13– 6	15– 0	106	12– 9	90	85	59	45·5
26–x	5	108	9– 6	9– 2	9– 4	104	10– 3	114	110	—	—
26–y	5	108	10– 1	10– 0	10– 1	112	10– 6	117	105	—	—
27–x	5	124	10– 5	11– 2	10–10	104	10– 9	104	100	48	36
27–y	4	124	10– 7	8–11	9– 9	94	10– 1	98	103	41	30·5
28–x	—	139	11– 6	11– 2	11– 4	98	12– 1	105	107	57	36
28–y	6	139	12– 0	12– 8	12– 4	106	12– 0	104	97	61	39
29–x	8	168	11–10	12– 1	11–11	85	12– 4	88	103	65	47
29–y	8	168	13– 2	11– 8	12– 5	89	12–10	92	103	69	44
30–x	4	116	10– 0	10– 4	10– 2	105	10– 3	106	101	40	29
30–y	4	116	9– 7	10– 6	10– 1	104	10– 3	106	102	44	26
31–x	8	156	14– 8	16– 6	15– 7	120	15– 5	118	99	61	56
31–y	8	156	14– 7	16– 0	15– 4	118	14– 4	110	94	58	45·5
32–x	7	151	12– 1	13– 4	12– 9	101	12– 3	97	96	52	44
32–y	8	151	11–11	15–10	13–11	110	12–11	103	93	55	47
33–a	5	158	11– 1	11– 0	11– 1	84	11– 7	88	105	51	34·5
33–b	6	158	10– 7	11– 5	11– 0	84	12– 0	91	109	54	36·5
34–x	5	139	9–10	11– 2	10– 6	91	11– 9	101	112	47	41·5
34–y	7	139	10– 3	12– 3	11– 3	97	12– 7	109	112	49	46·5
35–x	8	155	18– 9	17– 6	18– 2	140	13– 9	106	76	57	41
35–y	8	155	15– 9	16– 0	15–11	123	14– 1	109	89	60	43
36–x	8	164	12– 6	13– 5	13– 0	95	13– 0	95	100	54	46·5
36–y	8	164	13– 7	13– 4	13– 6	98	12– 9	93	93	53	46·5
37–x	5	114	11– 9	12– 4	12– 1	127	12– 3	129	106	48	37·5
37–y	5	114	10– 4	9–10	10– 1	106	10–11	115	108	47	38
38–x	8	158	13– 8	13– 9	13– 9	104	13– 3	100	97	67	46·5

Identical Twins (continued)

Pair.	Grade	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison McCall Spell. T. Score.	B.C. Arith. T. Score.
38–y	6	158	12–10	13– 6	13– 2	100	12– 5	94	94	60	39
39–x	7	148	12– 1	15– 8	13–11	112	13– 1	106	94	55	41
39–y	7	148	14–11	16– 0	15– 6	125	13– 5	109	87	57	39
40–x	6	186	10– 6	9– 0	9– 9	63	10– 6	68	108	46	41
40–y	6	186	10– 1	11– 0	10– 7	68	11– 0	71	104	47	41·5
41–a	2	119	10– 3	9– 0	9– 8	97	—	—	—	30	27
41–b	2	119	9– 6	9– 9	9– 8	97	—	—	—	31	28
42–x	8	151	10–11	12– 9	11–10	94	11– 9	93	99	48	40
42–y	7	151	10– 5	12– 5	11– 5	91	11– 9	93	103	46	34·5
43–a	5	128	11– 0	11–10	11– 5	107	10–10	102	95	47	37·5
43–b	5	128	10– 7	10– 8	10– 8	100	10– 5	98	98	44	30·5
44–a	8	163	15– 8	16– 0	15–10	117	14– 2	104	89	56	49·5
44–b	7	163	12– 5	16– 0	14– 3	105	12– 5	91	87	54	46
45–x	8	152	11– 2	12– 7	11–11	94	13– 2	104	110	52	42·5
45–y	7	152	13– 0	12– 7	12–10	101	12– 3	97	96	53	42·5
Fraternal Twins.											
46–a	3	116	9– 8	6– 6	8– 1	84	7– 8	79	95	29	26
46–x	3	116	10– 0	8– 3	9– 2	95	9– 4	97	102	36	31
47–x	5	133	11– 2	11– 8	11– 5	103	10–10	97	95	42	36
47–y	3	133	9– 5	9– 4	9– 5	85	10– 1	91	107	36	29
48–x	8	161	13– 3	15– 6	14– 5	107	14– 1	105	98	25	48
48–y	7	161	12– 9	11– 9	12– 3	91	12– 2	91	99	45	48
49–x	5	138	9– 7	10– 3	9–11	86	10– 4	90	104	41	35
49–y	5	138	11– 2	10– 4	10– 9	94	10– 4	90	96	40	31
50–x	6	177	11– 6	11– 5	11– 6	78	11– 5	77	99	55	46
50–y	8	177	11– 9	13– 3	12– 6	85	13– 4	90	107	60	47
51–x	—	121	9– 0	8– 1	8– 7	85	8– 8	86	101	32	25
51–a	—	121	10–11	10– 7	10– 9	107	10– 6	104	98	44	34
52–x	—	135	11– 4	11–11	11– 7	103	—	—	—	—	—
52–a	—	135	10–11	10–11	10–11	97	—	—	—	—	—
53–x	6	137	10– 8	13– 0	11–10	104	12– 7	110	106	—	—
53–y	aux.	137	9–10	7– 6	8– 8	76	7– 7	66	88	—	—
54–a	7	156	13– 1	12–11	13– 0	100	13–11	107	107	—	—
54–b	8	156	16– 1	13– 4	14– 8	113	14– 7	112	100	—	—
55–a	aux.	129	8–10	8– 0	8– 5	78	8– 6	79	101	—	—
55–b	3	129	10– 4	9– 7	9–11	92	9–10	92	99	—	—
56–x	8	168	15– 9	16– 0	15–11	113	13– 9	98	87	60	47
56–y	8	168	14– 9	13–10	14– 4	102	13– 1	93	92	55	48
57–a	—	122	9– 2	8– 9	9– 0	88	9– 2	90	102	36	28
57–b	—	122	10– 0	10– 1	10– 1	99	11– 1	109	110	53	35
58–x	6	180	11– 8	12– 3	12– 0	80	12– 1	81	101	57	43
58–y	8	180	16–11	14– 4	15– 8	104	13–10	92	88	67	53
59–a	7	176	11– 8	13– 5	12– 7	85	13– 2	90	105	63	43
59–x	8	176	11– 4	10– 8	11– 0	75	11– 5	78	104	61	40
60–x	6	131	11– 3	11– 5	11– 4	104	11– 4	104	100	47	38
60–y	5	131	9– 7	9– 3	9– 5	86	10– 2	93	108	38	30

Fraternal Twins (continued)

Pair.	Grade.	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison Mc-Call Spell. T. Score.	B.C. Arith. T. Score.
61–a	8	158	14– 5	15– 6	15– 0	114	13– 3	101	89	58	46
61–x	6	158	11– 3	12– 1	11– 8	89	11– 6	87	99	48	33
62–x	7	152	11– 3	12– 2	11– 9	92	12 –6	99	107	58	43
62–y	7	152	11– 2	12– 7	11–11	94	12–11	102	109	63	44
63–x	4	111	10– 1	9– 7	9–10	106	10– 1	109	102	58	23
63–a	4	111	10– 7	10– 0	10– 4	111	10– 4	112	100	62	32
64–x	7	142	11– 6	12– 1	11–10	100	13– 3	112	112	63	41·5
64–a	5	142	10– 9	11– 4	11– 1	93	11– 2	94	101	48	30·5
65–a	8	154	11– 9	14– 7	13– 2	103	14– 6	113	110	63	54·5
65–x	6	154	13– 8	13– 0	13– 4	104	12– 5	97	93	69	39
66–a	5	123	10–11	11– 4	11– 2	109	11– 1	108	100	44	31·5
67–b	4	123	9– 4	8–11	9– 2	89	10– 0	98	109	44	30
67–x	7	140	11– 2	12– 4	11– 9	101	12– 9	109	108	54	47
67–y	5	140	9– 2	10– 6	9–10	84	10– 9	92	109	48	44·5
68–a	8	163	14– 3	13– 3	13– 9	101	13– 0	96	95	69	54·5
68–b	7	163	15– 2	13–10	14– 6	107	13– 4	98	92	60	43
69–a	8	167	12– 1	14– 2	13– 2	94	12–10	92	98	61	—
69–b	8	167	14– 2	13– 7	13–11	100	13– 2	95	95	63	—
70–x	7	135	12– 2	12– 0	12– 1	107	11– 9	104	97	65	41·5
70–a	5	135	10– 7	10– 8	10– 8	94	10– 1	90	95	53	35
71–x	8	177	11– 6	12– 7	12– 1	82	11– 8	79	97	53	50·5
71–a	7	177	11– 6	11–10	11– 8	79	11– 9	80	101	54	35
72–a	8	160	12– 7	13–10	13– 3	99	13– 4	100	101	72	46·5
72–b	7	160	11– 3	11– 6	11– 5	85	11– 8	88	102	67	41·5
73–a	5	143	10– 6	11– 1	10–10	91	11– 2	94	103	58	33·5
73–b	6	143	12– 1	12–10	12– 6	105	11–10	99	95	60	43
74–x	—	131	9– 4	9– 3	9– 4	85	9– 4	86	100	35	26
74–y	—	131	10– 1	10– 1	10– 1	92	10– 0	92	99	42	30
75–a	—	128	10– 0	10–11	10– 6	98	10– 6	98	100	44	37·5
75–x	—	128	10– 0	9– 6	9– 9	91	9– 9	91	100	39	31
76–a	6	150	10– 3	11– 5	10–10	87	10–11	87	101	43	—
76–x	6	150	11– 2	11– 5	11– 4	90	11– 2	89	99	44	—
77–a	5	140	11– 2	12– 0	11– 7	99	11– 8	100	101	47	—
77–x	6	140	17– 2	17– 0	17– 1	146	13–10	119	81	55	—
78–a	6	149	12– 1	11–10	12– 0	96	12– 5	100	104	58	43
78–b	6	149	11– 1	10– 5	10– 9	87	11– 9	95	109	50	43
79–a	8	168	13– 8	15– 1	14– 5	103	13– 6	96	94	69	43
79–b	7	168	12– 9	11– 9	12– 3	88	12– 4	88	101	54	37·5
80–a	5	108	11– 2	10– 6	10–10	120	11– 3	125	104	42	31·5
80–x	5	108	9– 5	9– 1	9– 3	103	10– 0	111	108	41	29
81–x	5	132	11– 7	12–10	12– 3	111	11– 4	103	93	50	34·5
81–y	4	132	12– 4	10–10	11– 7	105	10– 7	96	91	52	29
82–x	5	126	10– 7	12– 5	11– 6	109	11– 4	108	99	47	36·5
82–a	5	126	9– 4	9– 6	9– 5	90	10– 0	95	106	43	34·5
83–x	6	145	14– 1	12–11	13– 6	112	12– 3	101	91	56	46
83–a	6	145	11– 3	12– 1	11– 8	97	11– 3	93	96	47	36

Fraternal Twins (continued)

Pair.	Grade.	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison Mc-Call Spell. T. Score.	B.C. Arith. T. Score.
84–x	8	160	11– 3	13– 0	12– 2	91	—	—	—	59	55·5
84–a	8	160	12– 6	17– 0	14– 9	111	—	—	—	61	50·5
85–x	6	132	11– 9	12– 2	12– 0	109	11–10	108	99	48	32·5
85–a	5	132	11– 8	11–10	11– 9	107	12– 4	112	105	49	36
86–x	7	154	10– 5	12– 0	11– 3	87	11– 7	90	103	47	41
86–a	7	154	11– 2	11– 2	11– 2	87	11– 7	90	104	49	37·5
87–x	7	147	12– 2	13– 9	13– 0	106	13– 1	107	101	53	42·5
87–y	6	147	9– 8	11– 0	10– 4	84	10– 2	83	98	45	35
88–x	5	127	10– 0	9– 8	9–10	93	9– 9	92	99	35	30·5
88–y	7	127	11– 4	14– 6	12–11	122	13–10	131	107	52	41
89–a	5	135	10– 0	—	10– 0	89	10– 6	93	105	44	34·5
89–x	5	135	10– 7	—	10– 7	94	10–11	97	103	47	36
90–x	6	142	11– 3	12– 2	11– 9	99	—	—	—	—	—
90–y	6	142	11– 4	11–11	11– 8	98	—	—	—	—	—
91–x	2	142	9– 1	8– 0	8– 7	72	—	—	—	—	—
91–y	5	142	10– 1	9– 7	9–10	83	—	—	—	—	—
92–x	5	144	9– 4	9–11	9– 8	80	—	—	—	—	—
92–a	5	144	9– 5	9–11	9– 8	81	—	—	—	—	—
93–x	8	164	15– 4	14– 2	14– 9	108	13– 2	96	89	61	48·5
93–a	6	164	10– 9	12– 2	11– 6	84	12– 0	88	104	49	44
94–x	5	176	9– 7	8–10	9– 3	63	10– 2	69	110	44	38
94–y	8	176	13–11	12–11	13– 5	91	14– 1	96	105	65	57·5
95–x	5	128	10– 5	10– 4	10– 5	97	10– 9	101	103	45	30·5
95–a	5	128	10– 8	9– 8	10– 2	95	10– 9	101	106	48	30·5
96–a	4	129	8– 8	8– 1	8– 5	78	9– 9	91	116	40	22
96–b	4	129	9– 2	7– 0	8– 1	75	9– 0	84	111	32	19·5
97–a	5	152	9– 4	9– 6	9– 5	74	10– 6	83	111	43	30
97–b	5	152	10– 7	9–10	10– 3	81	10– 6	83	103	44	41
98–a	5	146	9– 8	10– 8	10– 2	84	10– 9	88	106	43	41
98–x	6	146	13– 9	12– 7	13– 2	108	12– 4	101	94	49	37·5
99–a	8	152	11–11	12–10	12– 5	98	12– 3	97	99	54	37·5
99–x	7	152	14– 1	13– 3	13– 8	108	13–11	110	102	56	45·5
100–x	6	170	11– 9	12– 2	12– 0	84	11– 6	81	96	49	43
100–y	6	170	10– 8	11– 4	11– 0	78	11– 7	82	105	51	36
101–a	7	136	13– 5	13– 4	13– 5	118	13– 0	115	97	60	48·5
101–x	7	136	12–10	13– 6	13– 2	116	12– 4	109	94	63	44
102–x	3	113	10– 0	8– 9	9– 5	100	9– 4	99	100	40	26·5
102–y	3	113	9– 7	8– 5	9– 0	96	9– 0	96	100	33	21·5

APPENDIX C

ORIGINAL DATA OBTAINED FOR ORPHANS

Note.—All males are designated by "a"; females by "x."

Orphan	Years in home.	Age in months.	M.A. from multi-mental scale. Y–M.	M.A. from N.I.T. Y–M.	Composite M.A. Y–M.	Composite I.Q.	E.A. Stanf. Ach. Y–M.	E.Q. Stanf. Ach.	A.Q. Stanf. Ach.	Morrison McCall Spell. Score.	B.C. Arith. T. Score.
1–x	4–0	188	12–7	12–5	12–6	80	12–10	82	103	49	36
2–x	5–0	189	15–0	16–0	15–6	98	12–9	81	82	48	44
3–x	5–6	164	12–11	14–2	13–7	99	12–9	93	94	48	43
4–x	2–6	168	12–4	13–3	12–10	91	12–1	86	95	47	39
5–a	3–0	191	11–1	11–2	11–2	70	11–9	74	105	44	30
6–a	2–5	162	10–9	13–0	11–11	88	12–1	90	102	48	35
7–x	5–6	164	11–4	13–11	12–8	92	12–4	90	98	46	36·5
8–a	5–4	160	11–3	12–11	12–1	91	12–0	90	99	45	41
9–x	3–3	152	13–0	14–1	13–7	107	12–10	101	95	48	32
10–x	7–0	153	11–11	13–4	12–8	99	11–5	90	91	46	41
11–x	3–6	135	11–4	11–1	11–3	100	11–2	99	100	46	39
12–x	4–0	135	9–3	8–8	9–0	80	9–4	83	104	35	31·5
13–a	3–2	162	10–4	10–10	10–7	78	10–9	80	101	43	30
14–a	4–0	164	11–2	11–2	11–2	82	10–11	80	98	44	26·5
15–a	5–6	142	11–10	12–4	12–1	102	11–9	99	97	47	38
16–a	3–2	141	11–0	11–4	11–2	95	10–8	91	96	43	33·5
17–a	4–0	154	10–2	11–2	10–8	83	11–1	86	104	42	30·5
18–a	2–9	158	10–2	10–8	10–5	79	10–6	80	101	44	32·5
19–a	3–0	151	11–4	11–7	11–6	91	11–1	88	97	44	31·5
20–a	2–9	154	11–0	14–1	12–7	98	12–0	94	96	48	36·5
21–a	4–0	122	10–1	9–5	9–9	96	10–0	98	103	40	26·5
22–a	3–2	120	10–0	10–1	10–1	100	11–1	111	110	44	29
23–x	4–0	132	9–8	9–0	9–4	85	9–6	86	102	36	26
24–x	3–6	133	9–4	9–5	9–5	85	10–1	91	107	38	28
25–a	2–9	145	9–5	9–5	9–5	78	10–2	84	108	45	26·5
26–a	2–6	124	10–7	13–4	12–0	115	11–9	114	98	46	32
27–x	2–6	99	10–4	9–6	9–11	120	9–8	118	98	37	26·5
28–x	5–4	114	9–1	8–11	9–0	95	9–1	96	101	35	29
29–x	5–4	132	10–0	10–6	10–3	93	10–9	98	105	41	31

Note.—The above orphans were paired consecutively, that is, 1 and 2, 3 and 4, 5 and 6, etc.

In order to make a mate for 29–x, 24–x was paired with her. Thus 24–x was used twice.

The composite mental ages are printed devoid of fractional months.

In calculating the composite I.Q.'s, the exact composite M.A. was used in both twin and orphan data.

BIBLIOGRAPHY

1. Arey, L. B., " Direct Proof of the Monozygotic Origin of Twins," *Anat. Rec.*, Vol. XXIII, pp. 245–51.
2. Ballard, P. B., *Mental Tests.* Toronto: Hodder and Stoughton, 1920.
3. Binet, A., *The Development of Intelligence in Children.* Publications of the Vineland Training School, New Jersey, 1916.
4. Binet, A., " L'Intelligence des Imbéciles," *L'Année Psychologique*, 1909.
5. Burt, C., *Mental and Scholastic Tests.* London: P. S. King and Son, 1922.
6. Cattell, J. McK., " A Statistical Study of American Men of Science: III. The Distribution of American Men of Science," *Science*, New Series, Vol. XXIV, pp. 732–42.
7. Cobb, M. V., " Evidence bearing on the Origin of Twins from Single Ova," *Science*, New Series, Vol. LXVI, pp. 501–2.
8. Conklin, E. G., *Heredity and Environment.* Princeton University Press, 3rd ed., 1920.
9. Davenport *et al.*, " Twins," *Journal of Heredity*, Dec. 1919, Vol. X. p. 9.
10. Dexter, E., " On Family Resemblance Beyond the First Degree of Relationship," *School and Society*, April 26, 1924, pp. 501–2.
11. Dugdale, R. L., *The Jukes*, Thirty-third Annual Report of the Prison Association of New York, 1876.
12. Elderton, E. M., " On the Measure of Resemblance of First Cousins," *Eugenics Laboratory Memoirs*, Vol. IV. pp. 1–53. London: Dulau & Co., 1907.
13. Elderton, E. M., " A Summary of the Present Position with Regard to the Inheritance of Intelligence," *Biometrika*, 1923, Vol. XIV. pp. 378–408.
14. Estabrook, A. H., *The Jukes in 1915.* Washington, Carnegie Institution, 1916, pp. 85.
15. Fisher, R. A., " The Resemblance between Twins: a Statistical Examination of Lauterbach's Measurements," *Genetics*, Nov. 1925, Vol. X, No. 6, pp. 569–79.

16. Galton, F., *Hereditary Genius: an Inquiry into its Laws and Consequences.* London: Macmillan & Co., 1914. (First ed., 1869.)

17. Galton, F., and Schuster, E., *Noteworthy Families.* London: Eugenics Record Office, 1906.

18. Galton, F., *English Men of Science.* New York: Appleton & Co., 1874.

19. Galton, F., *Inquiries into Human Faculty and its Development.* New York: E. P. Dutton & Co., 1908. (First ed., 1881.)

20. Galton, F., *Natural Inheritance.* London: Macmillan & Co., 1889. (First ed., 1867.)

21. Gesell, A., "Mental and Physical Correlation in Twins," *Science Monthly*, 1922, Vol. XIV, pp. 305–31, 415–18.

22. Goddard, H. H., *The Kallikak Family.* New York: The Macmillan Co., 1912.

23. Gordon, K., "Psychological Tests of Orphan Children," *Journal of Delinquency*, Jan. 1919, Vol. XVIII, pp. 46–55.

24. Gordon, K., *The Influence of Heredity on Mental Ability.* Report of the Children's Department, State Board of Control of California, 1918–20.

25. Hart, B., and Spearman, C., "General Ability: its Existence and Nature," *Br. Journal of Psych.*, Vol. V. pp. 51–84.

26. Lauterbach, C. E., "Studies in Twin Resemblance," *Genetics*, Nov. 1925, Vol. X. No. 6, pp. 525–68.

27. Madsen, I. N., "Some Results with the Stanford Revision of the Binet-Simon Tests," *School and Society*, May 10, 1924, p. 559.

28. Merriman, C., "The Intellectual Resemblance of Twins," *Psychological Review*, 1924, XXXIII, Monograph 5, pp. 1–58.

29. Newman, H. H., *The Biology of Twins.* Chicago: University of Chicago Press, 1915.

30. Newman, H. H., *The Physiology of Twinning.* Chicago: University of Chicago Press, 1923.

31. Newman, H. H., *Evolution, Genetics and Eugenics.* Chicago: University of Chicago Press, 2nd ed., 1925.

32. Pearson, K., "On the Laws of Inheritance in Man," *Biometrika*, Vol. III. pp. 131–90.

33. Pearson, K., "On the Relationship of Intelligence to Size and Shape of Head and to Other Physical and Mental Characters," *Biometrika*, Vol. V, pp. 105–46.

34. Pearson, K., "The Inheritance of Psychical Characters," *Biometrika*, Vol. XII, pp. 367–72.

35. Popenoe, P., and Johnson, R. H., *Applied Eugenics.* New York: The Macmillan Co., 1918.

36. Sano, F., " A Convolutional Pattern of the Brains of Twins: a Study on Hereditary Resemblance in the Furrows of the Cerebral Hemispheres," *Philos. Trans. Roy. Soc.*, London, B 208, pp. 37–61.

37. Schuster, E., and Elderton, E., *The Inheritance of Ability*, Eugenics Laboratory Memoirs, 1907.

38. Spearman, C., *The Nature of Intelligence and Principles of Cognition.* London: Macmillan & Co., 1923.

39. Starch, D., " The Similarity of Brothers and Sisters in Mental Traits," *Psychological Review*, Vol. XXIV, 1917, pp. 235–38.

40. Stern, W., *Psychological Methods of Measuring Intelligence.* London: Warwick and York, 1913.

41. Terman, L., *The Measurement of Intelligence.* Boston: Houghton Miflin Co., 1916.

42. Thorndike, E. L., *Measurement of Twins*, Archives of Philosophy, Psychology and Scientific Methods, No. 1, 1905.

43. Thorndike, E. L., *Educational Psychology*, Vol. III. New York: Teachers' College, Columbia University, 1914.

44. Wiggam, A. E., *The Fruit of the Family Tree.* Bobbs-Merrill Co., 1924.

45. Woods, F. A., *Mental and Moral Heredity in Royalty.* New York: Henry Holt & Co., 1906.

Printed by Richard Clay & Sons, Ltd.,
at Bungay, Suffolk,
in Great Britain.