STUDIES IN TWIN RESEMBLANCE

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PROCEDURE

These studies concern themselves chiefly with the following questions:

(1) Do older twins show a greater degree of similarity than younger twins?

(2) Do like-sex pairs show a greater degree of similarity than unlike-sex pairs?

(3) Do twins show a greater degree of similarity in acquired abilities than in original nature?

(4) Do twins suffer any intellectual handicaps?

(5) Can symmetry reversal in handedness and whorl of head-hair be accepted as evidence of the monozygotic origin of twins?

(6) Do palm patterns offer any certain evidence of the monozygotic origin of twins?

(7) Is there any relationship between left-handedness and twinning?

Two hundred twelve pairs of twins were examined, divided according to sex, as follows:

Boy-boy pairs	71
Girl-girl pairs	78
Boy-girl pairs	63
Total	212

These twins varied in age from 90 months to 238 months and were distributed through the school grades from the third to the twelfth.

THE DATA COLLECTED

The data were all collected in the schools of seventeen cities of southern Wisconsin. To insure a random sampling, careful inquiry was made in each school for all the twins enrolled. In some instances this task was performed by the census officer who compiled a list of twins from his records. This is the best procedure, wherever such records are available. Other investigators have called attention to the fact that unlike-sex twins are likely to be overlooked. The ratio between the number of pairs examined, 71 ab : 63 ax : 78 xy, corresponds fairly well with the accepted ratio. With few exceptions the measurements were all taken by the author, who also did most of the scoring of the test papers. While ideal conditions

Measurements	*Number of pairs*
Terman group test of mental ability	113
National intelligence test	97
Thorndike-McCall reading scale	203
Courtis standard research tests, series B:	
Addition	206
Subtraction	205
Multiplication	200
Division	174
Memory span for digits	210
Discrimination for lines	92
Discrimination for ovals	212
O-test for speed of movement	210
Kansas City hand-writing scale	204
Age	211
Grade	206
Section of grade	206
Height, standing	211
Height, sitting	197
Weight	208
Cephalic index	204
Color of eyes	206
Color of hair	205
Whorl of head-hair	186
Handedness	201
Palm patterns	200

for testing were not usually encountered, the conditions for any given pair of twins did not vary, so that comparisons from the standpoint of similarities may be made with considerable confidence.

Throughout these studies all males are designated by "a" or "b," the first letters of the alphabet; all females are designated by "x" or "y," the last letters of the alphabet. Each pair of twins is given a number and the

individuals of a pair are designated by the letters which denote their sex. Thus, 105-ab means a pair of boys; 217-xy means a pair of girls; while 195-ax means a boy-girl pair, of which 195-a is the boy and 195-x is the girl. The system can easily be extended to include triplets, or any number of multiple births. Thus, 113-xyz in the author's collection means a set of girl triplets. To refer to particular measures, for example, the intelligence quotient (I.Q.) of 113-x is 65; of 113-y, 69; and of 113-z, 76. By this method the identity of the individual is established by the same symbol that indicates his sex, an obviously useful device.

In figuring correlations the PEARSON coefficient was used. In all cases where the range was fairly large, the scattergram method was adopted, but with one modification. Like-sex twins are a special case in which correlations are sought between varying amounts of the same trait in different individuals. Ordinarily, the correlation is figured between different traits in the same individuals. It is customary to figure the correlation, for example, between ability in mathematics and language for any particular group, pairing the scores. But in the case of twins it is desired to know the correlation between the abilities of the pair in mathematics or in language, pairing the individuals. As a consequence, there is no principle to determine the axis upon which a particular member of a twin pair shall be placed. If numbers are drawn in pairs by chance and the smaller is always placed on one axis and the larger on the other, a spurious correlation results. To avoid such an effect each twin was entered twice in the scattergram, once on each axis. As a result the standard deviation of each scale was the same, a compensation in computation for the extra labor involved in the double entry.

In cases where the range of the scale was decidedly limited, as in memory span for digits, and in all cases where unlike-sex pairs of twins were involved, HULL'S modification of the THURSTONE formula was used:

$$r = \frac{(M_{AB}) - (M_A \times M_B)}{\sqrt{M_A{}^2 - M^2{}_A} \quad \sqrt{M_B{}^2 - M^2{}_B}}$$

where M_A is the mean of one variable and M_B is the mean of the other variable. The deviations are figured from zero. When applied to the special case of like-sex twins, the formula becomes:

$$r_{AB} = \frac{M_{AB} - \left(\frac{M_A + M_B}{2} \times \frac{M_A + M_B}{2}\right)}{\left(\frac{M_A{}^2 + M_B{}^2}{2}\right) - \left(\frac{M_A + M_B}{2}\right)^2}$$

To figure correlations between scores and age to derive coefficients for partialing out age, the formula becomes:

$$r_{AC} = \frac{\frac{M_{AC}+M_{BC}}{2} - \left(\frac{M_A+M_B}{2} \times M_C\right)}{\sqrt{\left(\frac{M_A{}^2+M_B{}^2}{2}\right) - \left(\frac{M_A+M_B}{2}\right)^2}\ \sqrt{M_C{}^2-M^2{}_C}}$$

Here, again, there are compensations for the extra labor of the double entry, r_{AC} and r_{BC} being equal. The partial correlation, with age held constant, was then computed by the usual formula. All coefficients of correlation reported in this study are coefficients of partial correlation, age having been held constant.

In all cases of unlike-sex twins, or combinations involving unlike-sex twins, the regular method of computing the PEARSON coefficient was used. Double entry was unnecessary, since sex determined the axis upon which each particular twin should be placed. These coefficients have been calculated twice. One hundred sixteen correlations of zero order were computed on HULL'S correlation machine as a check on the original computations. It is therefore apparent that great care has been exercised to insure accurate results.

This study was inspired by Doctor V. A. C. HENMON of the UNIVERSITY OF WISCONSIN and brought to completion under his direction. Many others have rendered valuable assistance, particularly Doctor CLARK L. HULL, also of the UNIVERSITY OF WISCONSIN, and R. A. FISHER, M.A., chief statistician of ROTHAMSTED EXPERIMENTAL STATION, Harpenden, England. It is perhaps not amiss to acknowledge with gratitude the coöperation of the twins who, with patience and long-suffering, volunteered as subjects for these investigations.

THE IDENTIFICATION OF MONOZYGOTIC TWINS

Direct evidence of the monozygotic origin of twins is supplied by the foetal membranes. WILDER (1904) gives a four-fold grouping of data bearing on the intra-uterine relationships of these membranes. A study of WILDER'S types leads to the impression that it is not possible in every case, owing to the great diversity of conditions, to make an unequivocal classification. NEWMAN (1917) asserts that the presence or absence of more than a single corpus luteum will establish beyond doubt the monozygotic or dizygotic origin of a pair of twins. Since it can only be obtained by operation during pregnancy or by post-mortem examination of the

mother after birth, such evidence is rarely available. A common placenta is also considered as proof of one-egg origin, as is a common chorion. It is apparent, of course, that such evidence can not be secured by anyone except the obstetrician, particularly after the twins have reached school age, the period which lends itself most readily to an extensive investigation. If any practical grouping of twins as to their zygotic origin is to be effected, other evidence must be sought.

Biologists maintain that one-egg twins are always of the same sex. This is due to the fact that sex is determined zygotically at the time of fertilization. The theory states that there are two kinds of sperm and but one kind of egg, and the sex of the individual depends on whether a male-producing or a female-producing sperm fertilizes a particular egg. Therefore, a fertilized egg which twins, can produce individuals of one sex only.

In this connection sex ratios among twins are significant. The problem has been carefully considered by several investigators, notably NEWMAN (1917), COBB (1915) and MERRIMAN (1924). The data are given in table 1.

TABLE 1

Table showing sex ratios among twins.

	AB	AX	XY
Twin population	234,497	264,098	219,312
Ratio	.88	1.00	.83
Twin population	1118	1193	1023
Ratio	.93	1.00	.87

The United States Census affords additional data on sex ratios. In 1921 there were reported in the birth-registration area of the United States a total of 20,021 cases of twins of which 38,733 were live births and 1309 were still births, making a total of 40,042 twins. It will be noted by the following tables that the figures approximate the 1 : 1 : 1 ratio more closely than any data heretofore reported.

TABLE 2

Distribution of the number of pairs of twins (including still births in all cases where there was at least one live birth) by sex and color, reported in the birth-registration area of the United States in 1921.

RACE	AB	AX	XY	TOTAL
White	5952	6162	5821	17,935
Colored	687	736	663	2,086
Total	6639	6898	6484	20,021

TABLE 3

Sex ratios of twins, based on table 2.

RACE	AB	AX	XY
White	.97	1.00	.94
Colored	.93	1.00	.90
All cases	.96	1.00	.94

The biological argument is, that if sex is determined at the time of the fertilization of the egg, then there ought to be, by the law of chance, as many twin pairs of unlike sex as of like sex. But the actual facts are that there are twice as many like-sex pairs as unlike-sex pairs. The actual ratio is approximately 1 : 1 : 1 while the theoretical ratio is 1 : 2 : 1. NEWMAN (1917, p. 10) concludes that "the only satisfactory explanation of this discrepancy between the observed and the expected ratios appears to be that *nearly half of all same-sexed twins are monozygotic and hence morphologically stand for but one individual to a pair.*" It follows, then, that about one-fourth of all twin births are of monozygotic origin. MERRIMAN (1924) took the actual ratios instead of the approximate ratio of 1 : 1 : 1 and concluded that the number of monozygotic twins is about three-eighths of the total number of like-sex twins. This, then, is the first clew to the indirect identification of one-egg twins. All twins of unlike sex may be regarded as fraternal; monozygotic twins are found only among like-sex pairs and constitute about three-eighths of that group. While this simplifies the problem somewhat, it leaves the zygotic identification of one-half of the twin population a mystery, since it is just as difficult to say with certainty which twins of the like-sex pairs are monozygotic, as which are dizygotic.

For the identification of one-egg twins other characteristics than those of sex must be sought. Among the most promising of these is what is called symmetry reversal or mirror imaging.

It finds all degrees of expression from complete reversal of stomach, heart and viscera in conjoined twins and double monsters to the mirror-imaging of friction-ridge patterns, reversal in direction of the whorl of the head-hair, and right-handedness in one twin and left-handedness in the other. If twinning is due to fission, as some biologists maintain, symmetry reversal is a condition which may be expected from a developmental standpoint and can therefore be accepted with considerable confidence as evidence of one-egg origin. NEWMAN (1917, p. 152) says,

"The two phenomena [mirror-imaging and polyembryony] are so closely related that it is my belief that the occurrence of symmetry reversal or mirror-imaging in twins or double monsters may safely be taken as a criterion of their monozygotic origin."

It seems natural to expect that the product of a single egg which would ordinarily have produced a single bilaterally symmetrical individual, should show symmetry in its halves. Symmetry reversal in conjoined twins, where there is no doubt of monozygotic origin, is a well-attested fact and there is no reason to suppose that the same phenomenon may not manifest itself in separate one-egg twins.

It has been pointed out by NEWMAN (1917) that, due to intra-uterine hazards, unequal nutrition and inequality in somatic segregation, it is not safe to conclude that lack of similarity in unit characters is absolute evidence of dizygotic origin. It is quite possible that some unlike twins may be duplicates. On the other hand, it is just as probable that some twins which are very similar, even identical in some traits, are not monozygotic. A summation of all the evidence, sex, symmetry reversal, and striking similarities may lead pretty close to the truth. But with our present knowledge of the facts, any grouping of twins as monozygotic or dizygotic, on the basis of indirect evidence, must be largely experimental. Such an experimental grouping might be effected on the following characters:

1. Sex.
2. Symmetry reversal:
   a. Friction-ridge patterns of fingers, palms and soles.
   b. Reversal in direction of the whorl of the head-hair.
   c. Right- and left-handedness.
   d. Birth-marks, moles, freckle patterns, etc.
3. Identity or similarity of physical traits:
   a. Similarity of features.
   b. Texture and coloration of skin.
   c. Color of hair.
   d. Color of eyes.
   e. Height, standing and sitting.
   f. Weigh..
   g. Cephalic index.

SYMMETRY REVERSAL

The phenomenon of symmetry reversal often occurs in conjoined twins. The asymmetry of the unpaired organs of the normal individual in which the greater curvature of the stomach is to the left, the apex of the heart to the left, the aortic arch to the left, and the vena cava to the right, is

completely or partially reversed in one member of the pair. This condition is called "situs inversus viscerum" in contrast to the normal condition which is known as "situs solitus." Numerous instances have been reported and SPAETH and SCHATZ call attention to small deviations often found in separate one-egg twins (NEWMAN 1923).

The whorl of the head-hair (the crown, as it is commonly called) of the normal person is from left to right, or clockwise. It is for this reason that most people part their hair on the left; it naturally falls to the right. It is for the same reason that the mother of the boy whose head-hair whorls to the left has such difficulty in making her young son's hair "stay combed" when she parts it on the left. A slight change in technique would relieve her of her worries. The literature on twins has a few references to reversal of the whorl of the head-hair. NEWMAN (1923) mentions it, as does SANO (1916), but up to the time of this study no attempt seems to have been made to determine the frequency of its occurrence or the variations which the phenomenon manifests.

Sometimes this characteristic can be determined at a glance, especially if the hair is short. More frequently the hair requires considerable combing in order to discover the natural whorl. This is especially true in the case of girls. Long, fine hair sometimes assumes a false whorl but the true whorl can always be located close to the scalp. Double crowns are not unusual. My data reveal thirteen such cases. Occasionally, a sort of composite condition is found which is quite puzzling, but careful examination usually resolves it into two crowns lying very close together. No cases were found in which both members of a pair had double crowns.

One hundred eighty-six pairs of twins were examined to determine the whorl of the head-hair. The frequency of occurrence of this type of symmetry reversal is given in table 4. The plus sign (+) indicates a whorl to the right, or clockwise; the minus (−) sign indicates a whorl to the left, or counter-clockwise. Two signs in a parenthesis indicate a double crown, and the position of the signs indicate their position relative to each other on the head. Thus xy (+) (−+) means a girl-girl pair, the right-hand member of which has a double crown; and of these two crowns, the left-hand crown whorls to the left, the right-hand crown to the right.

As in the case of whorl of the head-hair, no effort seems to have been made, heretofore, to determine the amount of left-handedness among twins, though the condition in which one member of a pair is right-handed and the other left-handed has been recognized as symmetry reversal (NEWMAN 1923). In this study, the type of handedness manifested by any particular member of a pair of twins was determined by questioning, and

TABLE 4

Frequency of occurrence of symmetry reversal in whorl of head-hair in a total number of 186 cases.

TYPE	FREQUENCY BY PAIRS	FREQUENCY BY GROUPS	PERCENT
ab(+) (−)	8		
ab(−) (−)	1		
ab(+) (+−)	2		
ab(−) (+−)	2		
ab(+) (−+)	1		
ab(−) (−+)	0		
ab(+) (++)	0		
ab(−) (++)	0	14	7.53
xy(+) (−)	5		
xy(−) (−)	0		
xy(+) (+−)	2		
xy(−) (+−)	0		
xy(+) (−+)	0		
xy(−) (−+)	0		
xy(+) (++)	0		
xy(−) (++)	0	7	3.76
ax(+) (−)	15		
ax(−) (−)	3		
ax(+) (+−)	5		
ax(−) (+−)	0		
ax(+) (−+)	0		
ax(−) (−+)	0		
ax(+) (++)	1		
ax(−) (++)	0	24	12.90
Total symmetry reversal	45	45	24.19
ab(+) (+)	51	51	27.41
xy(+) (+)	56	56	30.10
ax(+) (+)	34	34	18.27
Total.....	186	186	99.97

sometimes by experiment. Most twins when asked "Are you right- or left-handed?" replied unhesitatingly, "Right." When a twin reported himself as left-handed, he was questioned further. It was discovered that many individuals who are naturally left-handed have learned to write with the right hand, or have made a transfer in many of the fundamental coördinations. To avoid error, therefore, as much as possible, such individuals were further asked, "How do you throw a ball?" or "How do you hold a needle when you sew?" Or the individual was handed a ball and asked to throw it to the examiner. This last method is particularly

LEGEND FOR PLATE 1

SYMMETRY REVERSAL IN WHORL OF THE HEAD-HAIR

This is a pair of twin boys who show symmetry reversal in whorl of the head-hair and in handedness. They are eleven years of age and both are in the fourth grade. In height, sitting, "b" is the taller by 4 millimeters, and in weight, the heavier by half a pound. The eyes of both are blue and the hair is a deep chestnut. They have the same intellectual ability. Table 5 below will reveal other resemblances. "a" is fifteen minutes older than his brother. "b" says he was left-handed in childhood but broke his arm about the fourth year. He still chores with the left hand. These twins may be of one-egg origin, but there is no unequivocal evidence of such a genesis.

TABLE 5

TRAIT	A	B	DIFFERENCE
Age	142 mo	142 mo	None
Grade	4	4	None
Section	2	2	None
Height, sitting	750 mm	754 mm	4 mm
Height, standing	1389 mm	1418 mm	29 mm
Weight	74.5 lb	75.0 lb	0.5 lb
Skull, length	184 mm	191 mm	7 mm
Skull, width	151 mm	149 mm	2 mm
Cephalic index	0.82	0.78	0.04
Color of eyes	Blue	Blue	None
Color of hair	Deep chestnut	Deep chestnut	None
Handedness	Left	Right (?)	Symmetry reversal
Whorl of head-hair	Clockwise	Counter-clock	Symmetry reversal
Main-line formulae	(7.5.5.4) (9.0.5.5)	(8.6.5.4) (11.7.5.5)	
Patterns	(oo oo oo oo xo xx)	(oo oo oo oo xx xx)	
Intelligence quotients	0.75	0.77	0.02
Reading quotients	0.77	0.77	None
Memory for digits	5	5	None
O-test: speed of movement	123	121	2
Handwriting, quality	6.75	7.75	1.00
Handwriting, speed	24	28	4


189-A
189-B


189-A
189-B

useful with small children. In some instances a tendency toward ambidexterity was found.

The frequency with which symmetry reversal in handedness occurs is shown in table 6. The same symbolism is used as in the case of the whorl of the head-hair. The plus sign (+) means right-handedness; the minus sign (−), left-handedness.

TABLE 6

Frequency of occurrence of symmetry reversal in handedness in a total number of 201 cases.

TYPE	FREQUENCY BY PAIRS	FREQUENCY BY GROUPS	PERCENT
ab(+) (−)	15		
ab(−) (−)	0	15	7.46
xy(+) (−)	7		
xy(−) (−)	1	8	3.98
ax(+) (−)	14		
ax(−) (−)	1	15	7.46
Total symmetry reversal	38	38	18.90
ab(+) (+)	54	54	20.86
xy(+) (+)	61	61	30.34
ax(+) (+)	48	48	23.88
Total.....	201	201	99.98

Combining tables 4 and 6 above reveals a surprising frequency of symmetry reversal. Of the 201 pairs of twins examined, 69 pairs, or 34.30 percent, show one or the other type of reversal and 14 pairs or 6.96 percent show both types. Of these 69 pairs, twenty-three are ab or boy pairs; 15 are xy or girl pairs; and 31 are ax or unlike-sex pairs.

While the data show an unexpected frequency of symmetry reversal they also reveal an extraordinarily confusing fact; namely, symmetry reversal in unlike-sex pairs. Some biologists look upon symmetry reversal as evidence of the monozygotic origin of twins. NEWMAN (1917) has expressed the belief that almost any kind of symmetry reversal may be accepted as evidence of monozygotic origin. WILDER has attempted a classification on the basis of symmetry reversal in friction-ridge patterns. But one-egg twins are said to be always of the same sex and here we have 31 pairs of twins of unlike sex which show unmistakable symmetry reversal in handedness and crown, while 14 show both types. The facts force us to the conclusion that symmetry reversal of these two types can

not be accepted as evidence of the monozygotic origin of twins, or else identical twins are frequently of unlike sex.

These apparently irreconcilable facts tempt to speculation. If monozygotic twins are always of the same sex, can we find an explanation of symmetry reversal in unlike-sex pairs?

Let us take a specific case, pair 158-ax, in which a, the boy, is right-handed and x, the girl, is left-handed. The probabilities are that two eggs were fertilized, one of which produced a, the other, x. The a-egg developed naturally into a normal right-handed boy. The x-egg, however, was retarded in its development, either by the presence of the contemporaneously fertilized a-egg or some other cause, and lost its axiate organization, becoming potentially an egg which would have produced a pair of monozygotic female twins. The a- and the x-eggs at this stage of development represent a set of triplets in which a is fraternal to x and y, x and y being duplicate to each other, that is, pair 158-ax becomes 158-axy. But for some unknown reason, during the course of early development, the right-hand axis of the x-egg degenerated and lost its potency while the left-hand axis reached maturity. The result is a surviving axis which shows symmetry reversal, not to the a-egg, but to the suppressed axis of the x-egg. The result is clearly a case of fraternal twins of the ax type showing symmetry reversal.

Any number of combinations of this sort are possible, and the suggestion goes far to explain what otherwise seem to be contradictory facts. Pair 115-ab is an interesting case, a being an ambidextrous boy with a double crown, one whorling to the right, the other to the left; while b is a normal right-handed boy with a single crown whorling to the right. Judging by the symmetry reversal manifested, a and b should be monozygotic. But note the summary of the measures of the pair, as given in table 7. In my opinion, nearly all the available evidence, both mental and physical, indicates a dizygotic origin. The differences are quite striking, particularly in progress in school, height sitting, weight, skull measurements, intelligence and reading quotients, palmar main-line formulae and patterns. While similarities and differences can not be accepted as proof of either the monozygotic or dizygotic origin of twins, the probabilities are that pair 115-ab represents two contemporaneously fertilized eggs, the b-egg developing into a normal boy, right-handed with a single crown; while the a-egg lost its axiate organization and became potentially a pair of monozygotic twins. But at a later stage the whole egg regained its single axiate organization, the only evidence of the disorganization remaining being the ambidexterity of a and his double crown. Thus, a represents two

axes, one of which shows symmetry reversal to the other and only incidentally to the b-egg.

The suggestion leads to many complex combinations, but this is exactly what is needed to explain the variable facts which the problem presents. There are in my collection, data on a set of triplets, 113-xyz, of which z is undoubtedly fraternal to x and y. This conclusion is justified both by the circumstances of birth and by the physical and mental measurements.

TABLE 7

Measurements of a pair of boy twins showing symmetry reversal in whorl of the head-hair and handedness.

TRAIT	A	B	DIFFERENCE
Age	16 yr	16 yr	None
Grade	10 high	9 high	1 year
Height, standing	171.7 cm	174.4 cm	2.7 cm
Height, sitting	86.9 cm	91.4 cm	4.5 cm
Weight	126.75 lb	175.25 lb	48.5 lb
Skull, length	19.8 cm	20.3 cm	0.5 cm
Skull, width	15.3 cm	14.9 cm	0.4 cm
Cephalic index	0.772	0.733	0.039
Color of eyes	Light brown	Light brown	None
Color of hair	Deep chestnut	Chestnut-black	Some
Crown	(+−)	(+)	Symmetry reversal
Handedness	Left	Right	Symmetry reversal
Palm formulae	(11.9.7.5) (11.9.7.5.)	(10.8.6.3) (7.9.7.5)	Considerable
Palm patterns	(oo oo oo xx oo rr)	(xx xx rr ox xx rr)	Marked
Intelligence quotient	0.86	0.75	0.11
Reading quotient	0.71	0.61	0.10
Arithmetic, accuracy	29	28	1
Arithmetic, speed	36	39	3
Memory digits	6	8	2
Speed of movement	144	72	72
Discrimination of ovals	0.834	0.700	0.13
Handwriting, quality	9.50	8.25	1.25
Handwriting, speed	88	64	22

Z was born first, while x and y followed together shortly after. Z, when examined, was a sophomore in high school; while x and y had dropped out of school in the eighth grade. Z seems to be normal physically, and well developed; x and y are extremely nervous, and dependent upon z in all their activities. Quoting from my notes, "z took the attitude of a mother toward the other two, answered questions for them and gave them instructions." But the most interesting fact is that x and y show no symmetry reversal in either handedness or crown while z is left-handed and her crown whorls to the left. Do we have here what was at one stage of

development potentially a set of quadruplets derived from two eggs, z being the only surviving axis of one of the eggs?

The intimate relationship between left-handedness and twinning has been mentioned by DANFORTH (1919, p. 400) who says, "Rather a surprising number of twin pairs seem to be composed of one right- and one left-handed individual." My data show that at least 19 percent of all twin pairs are composed of a right- and a left-hander. The probabilities are that the percentage is much larger for the reason that the method of examination would fail to take account of transfers. As indicated before, an attempt was made to determine native left-handedness by requiring the execution of some complex coördination like throwing a ball or holding a needle while sewing; but to ascertain the actual amount of left-handedness among twins, some more scientific method is essential.

JONES (1918) made a study of handedness based on physical measurements. His conclusions are based on data secured from a total of 20,000 pairs of arms, half a dozen cadavers and a dozen unpieced skeletons. He found that the bones of the major arm, that is, the bones of the left arm of a native left-hander are larger than the bones of the right arm, and *vice versa*. Transfers can be determined by measuring the muscle swell of the biceps and the fore-arm. An investigation needs to be made by such a method to determine the actual amount of left-handedness among twins.

The intimate relationship between left-handedness and twinning is also revealed by other inquiries which I have just begun. For example, x is a right-handed female twin who married and gave birth to a girl with a crown which whorled to the left, who in turn gave birth to a left-handed daughter. This daughter bore seven children, 4 boys and 3 girls, of whom one boy is left-handed and one has a double crown; and one girl is left-handed. Twin y, the sister of x, bore a left-handed daughter. These genealogies are represented in figure 1 in the symbols used by JORDAN (1911):

represents a right-handed male

represents a left-handed male

represents a right-handed female

represents a left-handed female

The crowns are represented by plus (+) and minus (−) signs, the former indicating a whorl to the right; the latter a whorl to the left; two signs

together indicate a double crown. While incomplete, these genealogies are extremely suggestive.

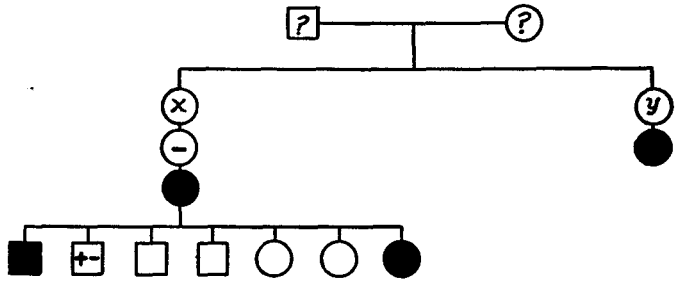


FIGURE 1

A similar case is found in figure 2, where x is a right-handed twin who gave birth to two boys and one girl, one boy being normal as far as handedness and crown are concerned, the other boy having a double crown, the girl being left-handed. The boy with a double crown is unmarried; the normal boy has three children, among whom is a left-handed boy. A fascinating field of investigation, which I think has never before been explored, is opened up here and holds promise of revealing facts which may shed considerable light on left-handedness and twinning.

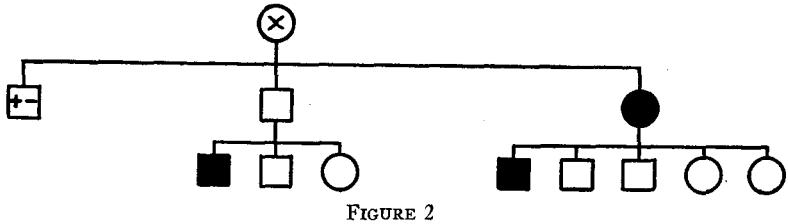


FIGURE 2

JORDAN (1911, p. 20) says

" . . . . inveterate left-handedness is invariably associated with general left-sidedness, i.e., left-leggedness, left eyedness, etc., ... and . . . the cerebral localization of this function (i.e., movement of the left hand) in the sinistro-manual is in the right cerebral hemisphere (next BROCA'S center in the third frontal convolution), the reverse condition obtaining in the dextro-manual."

It is also significant that HYRTL (1871) reports situs inversus viscerum, particularly of the vascular system, in left-handed individuals. Here, we have exactly the condition so frequently reported among double monsters and conjoined twins.

The frequency of left-handedness among twins, its occurrence in twin-bearing families, and its apparent relationship to situs inversus viscerum, suggest that the fundamental causes of twinning and left-handedness are the same. Is it not quite possible that we have in the left-handed indi-

vidual of a single birth the surviving axis of a bi-axiate egg which might have produced twins had not one axis been suppressed? Such an explanation, it seems to me, would clear up much of the mystery which surrounds the peculiar organization of the neural system of left-handed people.

JONES (1918) reports 4 percent of the population as natively left-handed. His data must have included measurements of some twins, though such a fact is nowhere indicated. If this 4 percent of the population represents in each case the surviving left axis of a bi-axiate egg, then by the law of chance there should be an equal number of individuals who represent the surviving right axes of bi-axiate eggs in which the left axis has degenerated. There is no way of identifying these individuals. But the total number of individuals who are the product of such development is therefore probably 8 percent, twice the number of left-handed individuals. If we add to this the 2 percent of the population who are twins, we have in the general population a total of 10 percent of potential twinning. Or perhaps it would be better to say that in 10 percent of the population the same causes operate to interfere with the normal development of the fertilized egg and the consequent neural organization of the individual. Incidentally, it is interesting to note that of the total number of 793 left-handed individuals examined by JONES, 498 are males and 295 are females, or in terms of percentage, 63 percent are males and 37 percent females. Of the forty left-handed twins examined by myself 23, or 58 percent are males; 13, or 42 percent, are females. These figures reveal a consistent preponderance of males in both cases.

JONES's figures and my own furnish data upon which the correlation between left-handedness and twinning can be reckoned. The United States Census for 1921 reports a total number of live births in the birth-registration area of 1,714,261 and a total number of live births from twin labors of 38,733.[1] According to these figures, the number of twins in each hundred of the population is 2.25, or as DAVENPORT (1920, p. 123) reports, "the average proportion of labors which are twin labors is 1.1 percent for the population as a whole," that is, 2.2 twins in every 101 of the total number of children born. Bearing in mind that JONES reports 4 percent of the population left-handed and that my data show 10 percent

[1] Calculations must be based on total live births, since figures of the number of still births for white and colored populations separately are not available. This causes a slight error augmented somewhat by the fact that the number of live births in twin labors includes "still births in all cases where there was at least one live birth." (Bureau of the Census, Birth Statistics, Seventh Annual Report, 1921.)

of the twin population left-handed, we can set up a four-fold table (table 8).

It has been noted by LOMBROSO that considerable left-handedness exists among lunatics and criminals,—swindlers, murderers and ravishers. It would be extremely interesting to know whether twins contribute to

TABLE 8

Four-fold table showing degree of relationship between left-handedness and twinning.

	Number left-handed per 1000 population	Number right-handed per 1000 population	Totals
Number of twins per 1000 population	a 2.2	b 19.8	22
Number not twins per 1000 population	c 37.8	d 940.2	978
Totals	40.0	960.0	1000

$$r = \cos\left(\frac{\sqrt{bc}}{\sqrt{ad}\ \sqrt{bc}}\right)180^\circ \quad r = .437 \pm .034$$

criminality or not and to what extent. The available data seem to indicate that there may be a relationship between a disturbed organization of the nervous system and moral lapses.

It should be noted that symmetry reversal of handedness and crown occur in only about 34 percent of the twin population. There may not always be such clear evidence of disturbance of the neural organization, but the probabilities are that we are not yet in possession of all of the

facts which might indicate such a deranged condition. Almost 25 percent of the twins examined showed reversal of the whorl of the head-hair and it may be that this type of symmetry reversal has the same significance as left-handedness, namely, some disturbance of the organization of the nervous system. The data show that some twins manifest no symmetry reversal of the type under discussion; that some manifest one type or the other; and that some manifest both types. There may be other kinds of reversal, or less degrees of reversal, which we do not yet recognize.

Certain facts stand out clearly:

1. Symmetry reversal in handedness and whorl of the head-hair cannot be accepted as evidence of the monozygotic origin of twins, assuming that such twins are of like sex.

2. Left-handedness and reversal of the whorl of the head-hair are intimately associated with human twinning.

The evidence suggests the very probable existence of certain other facts:

1. The causes which operate to produce twins probably also operate to produce left-handed individuals.

2. These causes affect about ten percent of the population.

PALM PATTERNS

The collection of the friction-ridge patterns of the palms of about two hundred twins examined during this study was made possible through the application of an inkless method of finger printing developed by Dr. J. H. MATHEWS, Professor of Chemistry at the UNIVERSITY OF WISCONSIN. The method consists in soaking blotter paper in a chemical solution until the blotter is thoroughly impregnated. The blotter is then removed from the tray and the palm pressed firmly upon it so that the solution adheres to the friction ridges. The palm is then placed momentarily upon photographic paper and the result is a beautiful print of the friction ridge patterns. The print is fixed in "hypo" like any ordinary photographic print. The prints illustrated in this study were produced by this method. With materials handy and an assistant to number the prints, an operator can average about a pair of palms a minute. Since the formula leaves no residue on the hands of the subject and since it is not "mussy" it has many advantages over the ink method of printing. While the method had not been worked out in detail at the time of this study, it served the purpose so admirably that it is to be hoped that Doctor MATHEWS will bring it to perfection, if not for commercial purposes, at least for scientific purposes.

The method of classification used is that of WILDER (1916), with one deviation. WILDER uses a small "x" to denote the *absence* of a line. But in view of the fact that in designating patterns the "x" is used to indicate the *presence* of a pattern, it seems less confusing to use the "o" throughout to indicate *absence* and the "x" to indicate *presence*. This is consistent with the method used in plantar designations where the "o" stands for "open field."

The purpose of this study in palm patterns was to distinguish the monozygotic twins from the dizygotic on the basis of identical or at least similar characteristics and mirror-imaging. WILDER (1916) has made such attempts but has met with indifferent success. NEWMAN (1917, p. 157) says,

> "It must not be lost sight of, however, that identity in friction-ridge patterns of twins makes their monozygotic origin highly probable. Identity may demonstrate monozygotic origin, but lack of identity does not disprove the possibility of monozygotic origin."

It would seem, then, that while not all monozygotic twins could be distinguished by similarities in palm patterns, a goodly number could be thus identified.

Naturally the most interesting group of patterns is that of the twins showing symmetry reversal in handedness and whorl of the head-hair. Table 12 gives the main-line formulae and the patterns for fifty-one pairs of this group, and in addition, the same data for twenty-three like-sex pairs which do not show symmetry reversal in handedness or crown. Probably the first fact to strike the student who studies this table is the frequent occurrence of one aberrant pattern. In many instances where three palms show identical or very similar main-line formulae, the fourth shows a marked variation. WILDER (1916) noted this in his studies and was much puzzled to find an aberrant plantar pattern in the case of Mary, one of the pair of conjoined twins. NEWMAN (1917, p. 157) attributes this phenomenon to somatic segregation:

> "In certain monozygotic human twins it might readily happen that by somatic segregation the paternal condition of friction ridges would go to one individual and the maternal to the other, or there might be a partial segregation of important elements of the pattern so that they would be distributed differently in the two."

Whatever the cause, the variation is of relatively frequent occurrence in the main-line formulae of the palms. Instances will be noted in 103-ab, 160-ab, 229-ab, 275-ab, 296-ab; 171-xy, 183-xy, 185-xy, 279-xy; 198-ax, 222-ax; 150-ab, 214-ab, 107-xy, 177-xy, 183-xy. While the difference is

LEGEND FOR PLATE 2

DISSIMILARITY IN PALM PATTERNS

These prints are of a pair of boy twins showing symmetry reversal in whorl of head-hair, the crown of "a" whorling counter-clockwise. Their palms show striking variations, particularly in the thenar and the first interdigital patterns of "b." NEWMAN (1917, p. 157) suggests that such a condition is due to somatic segregation, one twin inheriting the paternal condition of friction-ridge patterns, the other, the maternal.

sometimes comparatively slight, at other times it is considerable. Furthermore, the phenomenon occurs in all groups. A study of the patterns reveals a similar condition. Striking instances are seen in 229-ab, 183-xy, 185-xy, 222-ax. Slight variations occur more frequently. Of course, variations in palm patterns are to be expected with variations in main-line formulae, since the 2nd, 3rd and 4th interdigital patterns are usually determined by the main lines.

But suppose we try to pick out the one-egg twins. Let us take the case of E and L. The formulae for the palms are:

E, (11.0.7.5) (11.0.7.5) (oo oo oo oo oo xx)

L, (11.0.7.5) (11.0.7.5) (oo oo oo oo oo xx)

Here there is complete identity in main-line formulae and patterns. Shall we say that these twins are monozygotic? Before making a decision let us examine other evidence:

TABLE 9

The measurements of twins E and L.

THE TRAIT MEASURED	E	L	DIFFERENCE
Age	172 mo	172 mo	None
Grade	9 Low	9 Low	None
Height, standing	140.5 cm	139.7 cm	0.8 cm
Height, sitting	70.2 cm	69.6 cm	0.6 cm
Weight	67.50 lb	70.25 lb	2.75 lb
Skull, length	17.7 cm	17.8 cm	0.1 cm
Skull, width	14.2 cm	14.5 cm	0.3 cm
Cephalic index	0.802	0.814	0.012
Color of eyes	Light brown	Light brown	None
Color of hair	Deep chestnut	Deep chestnut	None
Handedness	+	+	None
Whorl of head-hair	+	+	None
Intelligence quotient	0.97	0.93	0.04
Reading quotient	1.15	1.22	0.07
Arithmetic, speed	66	58	8
Arithmetic, accuracy	42	44	2
Memory for digits	7	8	1
Discrimination of lines	18	14	4
Discrimination of ovals	0.650	0.884	0.234
O-test	138	122	16
Handwriting, speed	91	82	9
Handwriting, quality	12.5	12.0	0.5

In addition to this evidence, my notes, taken at the time of the examination, say, "Hands alike. Teeth, nose, texture of skin, coloration, eyebrows, same. *Identical.*" Are these twins identical?

Let us take another case of twins, that of P and V. Their main-line formulae and their patterns are:

P, (7.5.5.4) (7.5.5.5) (oo oo oo oo xx xx)

V, (7.5.5.4) (7.5.5.4) (oo oo oo oo xx xx)

There is enough asymmetry here to permit us to say that there is symmetry reversal in main-line formulae. The patterns are identical except in minutiae. Besides, V is left-handed and has a double crown (− +). A study of physical and mental traits likewise shows striking similarity:

TABLE 10

The measurements of twins P and V.

THE TRAIT MEASURED	P	V	DIFFERENCE
Age	119 mo	119 mo	None
Grade	4 low	4 low	None
Height, standing	127.1 cm	129.5 cm	2.4 cm
Height, sitting	70.4 cm	69.8 cm	0.6 cm
Weight	62.50 lb	56.00 lb	6.50 lb
Skull, length	18.1 cm	17.7 cm	0.4 cm
Skull, width	14.7 cm	14.1 cm	0.6 cm
Cephalic index	0.812	0.796	0.016
Color of eyes	Light brown	Light brown	None
Color of hair	Deep chestnut	Medium chestnut	Slight
Handedness	+	−	Symmetry reversal
Whorl of head-hair	+	− +	Symmetry reversal
Intelligence quotient	1.00	0.97	0.03
Reading quotient	0.95	1.02	0.07
Arithmetic, speed	14	16	2
Arithmetic, accuracy	2	1	1
Memory for digits	6	5	1
O-test	102	54	58
Discrimination of ovals	0.484	0.317	0.167
Handwriting, speed	33	57	24
Handwriting, quality	7	7	None

Perhaps the most significant differences are found in skull measurements, but even here the difference in cephalic index is not great. There is a slight difference in color of hair. In speed of movement the difference is marked; likewise in handwriting speed, though the difference is reversed. In quality of handwriting, the scale shows no difference.

That differences in physical traits must not be taken as conclusive evidence that any particular pair of twins is dizygotic, is pointed out by NEWMAN (1917, p. 162),

"It should be pointed out, however, that fairly marked dimensional *differences*, even at birth, could not be used as evidence against the monozygotic

origin of any particular pair of twins; in the armadillo, where the monozygotic origin is specific and unequivocal, there is frequently found a striking difference among the quadruplets of a given set. On the whole, then, it would seem inadvisable to use dimensional measurements, either at birth or in later life, as data for determining the degree of resemblance (coefficient of correlation) between twins."

Further on he says, (p. 171), speaking specifically of friction-ridge patterns,

"In the light of what I have found in armadillo quadruplets, which are unquestionably monozygotic, it does not seem safe to exclude from the category of monozygotic twins those that fail to show identity of pattern; the same practice, if applied to armadillo quadruplets, would lead to grave errors. It is probably safer to say that some monozygotic human twins, like some sets of armadillo quadruplets, are nearly identical, while others, like various quadruplet sets, may differ materially from each other."

In view of the symmetry reversal manifested in twins P and V, the remarkable correspondence in palm patterns, and assuming that differences in physical traits are not necessarily evidence disproving the monozygotic origin of any particular pair of twins, one is tempted to conclude that P and V are monozygotic.

TABLE 11

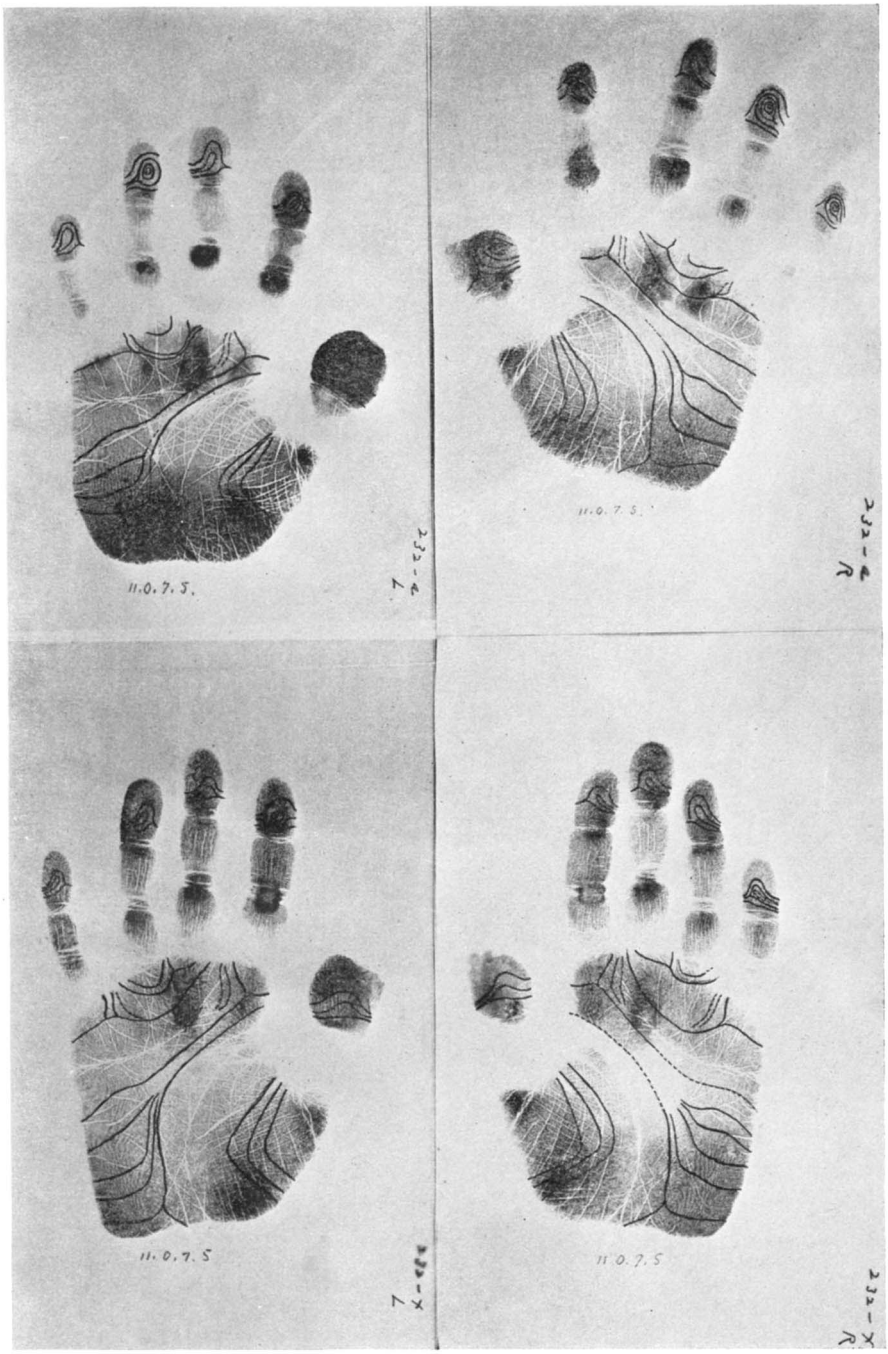
The measurements of twins A and C.

THE TRAIT MEASURED	A	C	DIFFERENCE
Age	116 mo	116 mo	None
Grade	4 low	4 low	None
Height, standing	114.8 cm	121.2 cm	6.4 cm
Height, sitting	64.8 cm	68.0 cm	3.2 cm
Weight	47.00 lb	53.25 lb	6.25 lb
Skull, length	18.1 cm	18.1 cm	None
Skull, width	14.5 cm	14.5 cm	None
Cephalic index	0.801	0.801	None
Color of eyes	Dark brown	Blue	Marked
Color of hair	Chestnut black	Light chestnut	Marked
Handedness	+	−	Symmetry reversal
Whorl of head-hair	+	+−	Symmetry reversal
Intelligence quotient	0.91	1.03	0.12
Reading quotient	0.76	0.91	0.15
Arithmetic, speed	25	21	4
Arithmetic, accuracy	17	9	8
Memory for digits	6	7	1
Discrimination of ovals	0.40	0.00	0.40
O-test	83	62	21
Handwriting, speed	44	39	5
Handwriting, quality	9.5	10.25	0.75

LEGEND FOR PLATE 3

IDENTICAL PALMS IN UNLIKE-SEX TWINS

An examination of these patterns reveals that they are almost identical. There is the characteristic suppression of line C in each palm and symmetry reversal, finger for finger, except in the thumbs. In fact, the only marked difference is in the apical pattern of the thumbs. These twins also show symmetry reversal, "x" having a double crown (+ −) and being left-handed. *But these twins are of unlike sex.* The case clearly shows that any zygotic classification of twins on the basis of either palm patterns or symmetry reversal is an extremely uncertain procedure. These are the prints of Anthony and Charlotte, 232-ax.


11.0.7.5.
11.0.7.5.
11.0.7.5
11.0.7.5

But before we make our decision let us examine another pair of twins, A and C. Their main-line formulae and their patterns are:

A, (11.0.7.5) (11.0.7.5) (oo oo oo oo oo rr)

C, (11.0.7.5) (11.0.7.5) (oo oo oo oo oo rr)

This striking correspondence extends as well to the apical patterns of the fingers (see plate 3), there being almost perfect symmetry reversal, finger for finger, except the thumbs. Not only do we have identical formulae and patterns, but we have also symmetry reversal in handedness, C, the left-handed twin, having also a double crown (+ −). The evidence of physical and mental measurement may also favor the theory of one-egg origin: We have some marked differences here, notably in color of eyes and hair, but we have complete correspondence in skull measurements. We have, to offset the differences in physical traits, four instances of symmetry reversal, in handedness, in crown, and in both palms. Are A and C monozygotic?

We have here, as far as palms are concerned, a case identical with the conjoined twins, Mary and Margaret, reported by WILDER (1916). The palms of all four hands are practically alike in pattern, and it may not, therefore, be correct to speak of mirror-imaging in this connection. NEWMAN (1917, p. 164) says of the case: "Since there is no asymmetry in the hands, there is no chance to observe symmetry reversal or mirror-imaging."

It seems to me, on the face of the evidence presented, that it is at least very probable that these three pairs of twins are identical. The evidence of the palm patterns alone seems to be perfectly clear. Add to this the evidence of symmetry reversal and reasonable similarity in physical and mental traits, the conclusion, in view of the theories which have been urged, is almost unavoidable that E and L, P and V, and A and C are monozygotic twins. This would certainly be my conclusion were it not for one fact which has not been considered. P (Paul) and V (Vivian) and A (Anthony) and C (Charlotte) are unlike-sex twins. E (Eleanore) and L (Lucille) are a pair of girl twins. Their numbers are respectively 155-ax, 232-ax and 274-xy. This does not mean, of course, that pair 274-xy is not monozygotic. This may be a pair of one-egg twins. But such a statement could be made on the basis of sex alone. If unlike-sex twins can be so misleading, may not like-sex pairs be even more so? It is evident that a classification of twins as monozygotic or dizygotic on the basis of palm patterns, or even a summation of evidence, may lead to very grave errors.

TABLE 12

Showing symmetry reversal in handedness and crown, and the main-line and palm-pattern formulae of 74 pairs of twins.

NUMBER	HAND	CROWN	MAIN LINES		PATTERNS
103 a	+	+	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo rr)
b	−	−	(11.8.7.5)	(11.9.7.5)	(oo oo oo ox oo rr)
115 a	−	+−	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo rr)
b	+	+	(10.8.6.3)	(7.9.7.5)	(xx xx rr ox xx rr)
140 a	−	+	(7.5.5.3)	(7.5.5.3)	(oo oo oo oo xo rr)
b	+	+	(7.5.5.3)	(9.7.5.5)	(oo oo oo oo xx rr)
148 a	−	X	(11.0.7.5)	(11.8.7.5)	(oo oo oo oo rr rr)
b	+	X	(11.0.7.5)	(11.9.7.5)	(oo oo oo ox ro rr)
149 a	−	+	(9.9.5.5)	(11.9.7.5)	(oo oo oo xx xo rr)
b	+	+−	(10.9.6.5)	(10.9.6.5)	(xo xo oo xx xx rr)
160 a	+	+	(7.5.5.3)	(7.5.5.3)	(oo oo oo oo xx oo)
b	+	−	(7.5.5.3)	(8.6.5.5)	(oo oo oo oo xx rx)
166 a	−	+	(9.8.5.4)	(10.8.6.5)	(oo oo oo ox oo xx)
b	+	+	(9.8.5.4)	(8.6.5.11)	(oo oo ox ro ox rr)
168 a	+	+	(7.5.5.5)	(9.7.5.5)	(oo oo oo oo xx xx)
b	−	+	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xx xx)
176 a	+	−+	(9.7.5.5)	(11.10.8.5)	(xx xx oo ox xo rr)
b	+	+	(9.0.5.5)	(9. 9.5.5)	(rr oo oo ox xo rr)
189 a	−	+	(7.5.5.4)	(9.0.5.5)	(oo oo oo oo xo xx)
b	+	−	(8.6.5.4)	(11.7.5.5)	(oo oo oo oo xx xx)
191 a	+	−	(9.9.5.4)	(11.10.6.5)	(oo oo oo xx oo rr)
b	+	+	(7.5.5.5)	(9. 7.5.5)	(xx xx oo oo xx rx)
229 a	−	+	(11.0.7.5)	(12.9.7.6)	(xx xx oo ox oo xx)
b	+	+	(11.0.7.5)	(11.0.7.5)	(rr oo oo ox oo rr)
238 a	+	+	(9.9.5.5)	(11.9.7.5)	(xo xo oo xx rr xx)
b	+	−	(11.8.7.5)	(11.9.7.5)	(oo oo oo ox xr rr)
244 a	+	+	(7.5.5.4)	(7.5.5.5)	(oo oo oo oo xx xr)
b	+	−	(7.5.5.5)	(7.5.5.5)	(oo oo oo oo xx rr)
254 a	+	+−	(11.8.7.5)	(11.8.7.5)	(oo oo rx oo rr rr)
b	+	+	(10.8.6.5)	(11.8.7.5)	(oo oo oo oo oo rr)

TABLE 12 (continued)

NUMBER	HAND	CROWN	MAIN LINES		PATTERNS
262 a	+	−	(11.7.5.5)	(11.10.8.5)	(oo oo oo ox xo xo)
b	+	+−	(11.9.7.5)	(11. 9.7.5)	(oo oo oo xx oo rr)
269 a	+	+	(11.9.7.4)	(11.9.7.5)	(oo oo oo xx oo xx)
b	−	X	(11.8.7.4)	(11.9.7.5)	(oo oo oo xx oo xx)
275 a	+	−	(11.0.7.5)	(11.0.7.5)	(oo oo oo or oo rr)
b	−	−	(10.0.6.5)	(11.0.7.5)	(oo oo oo oo oo rr)
276 a	+	−	(11.8.7.5)	(11.0.7.5)	(rr oo ro oo oo xx)
b	+	+	(11.8.7.5)	(11.0.7.5)	(rr oo rr ox rr xx)
296 a	+	+	(11.8.7.5)	(11.8.7.5)	(oo oo oo oo oo xx)
b	−	−	(11.8.7.5)	(11.9.7.5)	(oo oo oo ox oo rx)
302 a	+	+	(9.0.5.1)	(9.7.5.1)	(oo oo oo oo ox xx)
b	−	+	(10.8.6.1)	(8.6.5.4)	(oo oo oo oo ox xx)
303 a	−	+	(9.8.5.4)	(11.8.7.4)	(oo oo oo oo oo xx)
b	+	+	(7.5.5.4)	(7.5.5.4)	(oo oo oo oo xx xx)
305 a	−	+	(10.9.6.5)	(11.9.7.5)	(xr ?o rr xx xx xx)
b	+	+	(9.9.5.5)	(9.9.5.5)	(rr oo rr xx rr rr)
159 x	+	+	(11.8.7.5)	(7.5.5.5)	(oo oo oo oo ox xx)
y	−	+	(9.7.5.3)	(10.0.6.5)	(oo oo oo ox xo rr)
171 x	−	+	(11.9.7.4)	(11.9.7.5)	(oo oo oo xx oo xx)
y	+	+	(11.9.7.4)	(11.9.7.4)	(oo oo oo xx oo xx)
178 x	+	+	(9.7.5.4)	(11.9.7.4)	(oo oo oo ox xo xx)
y	−	+	(10.0.6.4)	(11.9.7.4)	(oo oo oo ox oo xx)
181 x	+	+	(11.9.7.5)	(8.6.5.5)	(oo oo oo xo ox rx)
y	+	−	(7.5.5.1)	(8.6.5.2)	(oo oo oo xx xx rr)
183 x	−	+	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo xx)
y	+	+	(9.7.5.5)	(11.9.7.5)	(oo oo oo rr xr xx)
185 x	+	−	(11.9.7.4)	(11.9.7.5)	(oo oo oo xx oo xo)
y	+	+	(11.9.7.5)	(11.9.7.5)	(xo xo oo xx oo oo)
196 x	+	+	(9.7.5.5)	(9.7.5.5)	(xo xo oo ox xo oo)
y	+	+−	(10.0.5.5)	(9.7.5.5)	(xx xx oo oo ox oo)

TABLE 12 (continued)

NUMBER	HAND	CROWN	MAIN LINES		PATTERNS
211 x	+	−	(9.0.5.3)	(11.9.7.5)	(oo oo oo ox oo rr)
y	+	+	(9.9.5.4)	(11.9.7.5)	(oo oo oo xx oo rr)
233 x	−	+	(7.5.5.5)	(7.9.7.5)	(xx xx oo xx xx rr)
y	+	+	(7.5.5.3)	(10.9.6.5)	(oo oo oo ox xo rr)
279 x	+	+	(11.8.7.4)	(11.9.7.4)	(oo oo oo ox oo xx)
y	+	+−	(11.8.7.4)	(11.8.7.4)	(oo oo oo oo oo xx)
293 x	+	−	(9.7.5.5)	(11.9.7.5)	(xx xx oo ox xr rr)
y	+	+	(11.9.7.5)	(9.9.5.5)	(oo oo oo xx rr xx)
101 a	+	+	(10.9.6.4)	(11.9.7.4)	(oo oo oo xx rr xx)
x	−	+	(10.9.6.4)	(11.9.7.4)	(oo oo oo xx rr xx)
132 a	+	+	(9.7.5.5)	(9.9.5.5)	(oo oo oo ox xx xx)
x	+	−	(11.8.7.5)	(10.7.6.5)	(oo oo oo ox xx xx)
137 a	+	−	(11.7.5.3)	(11.9.7.5)	(oo oo oo ox xo rr)
x	+	+	(10.9.6.5)	(11.9.7.5)	(oo oo oo ox rr rr)
138 a	+	−	(7.5.5.3)	(8.6.5.3)	(oo oo oo oo xx rr)
x	+	+	(7.5.5.3)	(10.9.6.3)	(oo oo oo ox xo rr)
155 a	+	+	(7.5.5.4)	(7.5.5.5)	(oo oo oo oo xx xx)
x	−	+−	(7.5.5.4)	(7.5.5.4)	(oo oo oo oo xx xx)
158 a	+	+	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xr rr)
x	−	+	(9.9.5.1)	(11.9.7.1)	(oo oo oo xx oo rr)
163 a	+	−	(7.5.5.5)	(9.7.5.5)	(ro oo oo oo xx oo)
x	+	+	(7.9.5.5)	(7.5.5.5)	(oo oo oo xo xx rr)
172 a	+	−	(9.7.5.3)	(9.8.5.3)	(oo oo oo oo xo rr)
x	+	−	(9.0.5.5)	(11.0.7.5)	(oo oo oo ox oo rr)
190 a	+	−	(11.0.7.5)	(11.9.7.5)	(xo xo oo ox oo rr)
x	+	+	(11.8.7.5)	(11.9.7.5)	(oo oo oo ox oo rr)
198 a	+	++	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xx rr)
x	−	+	(9.7.5.5)	(11.9.7.5)	(oo oo oo ox xo rr)
207 a	+	+	(11.8.7.5)	(11.9.7.5)	(xo xo xx ox xo rr)
x	+	+−	(11.7.7.5)	(11.9.7.5)	(oo oo oo ox xo rr)
222 a	−	−	(11.9.7.5)	(11.11.9.5)	(xx xx oo xx oo oo)
x	+	+	(11.9.7.5)	(11. 9.7.5)	(oo oo oo xx oo oo)

TABLE 12 (continued)

NUMBER	HAND	CROWN	MAIN LINES		PATTERNS
224 a	+	−	(11.8.7.5)	(11.9.7.5)	(oo oo oo xx oo rr)
x	+	+	(7.8.5.5)	(11.9.7.5)	(oo oo oo xx xx rr)
232 a	+	+	(11.0.7.5)	(11.0.7.5)	(oo oo oo oo oo rr)
x	−	+−	(11.0.7.5)	(11.0.7.5)	(oo oo oo oo oo rr)
246 a	+	−	(9.7.5.5)	(7.5.5.4)	(oo oo oo oo xx rx)
x	+	+	(7.7.5.5)	(11.9.7.5)	(oo oo xx xx xx rr)
272 a	+	+	(11.8.7.5)	(11.9.7.5)	(oo oo oo ox oo rr)
x	+	−	(9.7.5.5)	(11.8.7.5)	(oo oo oo oo xo xr)
287 a	−	+	(11.9.7.1)	(9.9.5.3)	(oo oo oo xx oo rr)
x	+	+	(9.9.5.3)	(10.9.6.5)	(oo oo oo xx oo rx)
102 a	+	+	(9.7.5.4)	(11.9.7.5)	(oo oo oo ox xo xx)
b	+	+	(9.7.5.5)	(7.5.5.5)	(oo oo oo oo ox rr)
150 a	+	+	(9.0.5.5)	(11.0.7.5)	(oo oo oo oo oo rr)
b	+	+	(11.0.7.5)	(11.0.7.5)	(oo oo oo ox oo rr)
162 a	+	+	(9.9.5.5)	(9.9.5.5)	(oo oo oo xx oo xx)
b	+	+	(9.7.5.4)	(9.7.5.5)	(oo oo oo oo xx xx)
179 a	+	+	(8.6.5.4)	(8.6.5.4)	(oo oo oo oo xx xx)
b	+	+	(8.6.5.4)	(8.6.5.4)	(oo oo oo oo xx rx)
180 a	+	+	(7.5.5.3)	(7.5.5.4)	(oo oo oo oo xx rx)
b	+	+	(7.5.5.4)	(7.5.5.4)	(oo oo oo oo xx xr)
214 a	+	+	(9.9.5.5)	(11.9.7.5)	(oo oo oo xx oo xr)
b	+	+	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo xr)
253 a	+	+	(9.9.5.3)	(10.9.7.5)	(oo oo oo xx oo oo)
b	+	+	(9.9.5.5)	(9.9.5.5)	(oo oo oo xx oo oo)
308 a	+	+	(11.0.7.5)	(11.0.7.5)	(oo oo oo oo oo xx)
b	+	+	(11.9.7.5)	(11.9.7.5)	(ro xo xx xx rr rx)
107 x	+	+	(8.6.5.4)	(8.6.5.4)	(oo oo oo oo xx xx)
y	+	+	(7.5.5.4)	(8.6.5.4)	(oo oo oo oo xx xx)
109 x	+	+	(10.0.6.5)	(8.6.5.5)	(xx xx oo oo ox oo)
y	+	+	(7.5.5.5)	(11.0.7.5)	(xx xx oo oo xo xo)
110 x	+	+	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xx xx)
y	+	+	(7.5.5.5)	(7.5.5.5)	(oo oo oo oo xx xx)

TABLE 12 (continued)

NUMBER	HAND	CROWN	MAIN LINES		PATTERNS
129 x	+	+	(11.8.7.5)	(11.9.7.5)	(xx oo oo ox oo rx)
y	+	+	(11.8.7.5)	(11.9.7.5)	(xx oo oo ox oo rx)
147 x	+	+	(9.9.5.4)	(9.7.5.4)	(oo oo oo xo ox xx)
y	+	+	(9.9.5.4)	(9.9.5.4)	(oo oo oo xx oo xx)
156 x	+	+	(11.9.7.4)	(11.9.7.4)	(oo oo oo xx oo xx)
y	+	+	(9.7.5.4)	(9.7.5.4)	(oo oo oo oo xx xx)
177 x	+	+	(7.5.5.3)	(8.6.5.3)	(oo oo oo oo xx rr)
y	+	+	(8.6.5.3)	(8.6.5.5)	(oo oo oo oo xx rr)
183 x	+	+	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo rx)
y	+	+	(9.7.5.5)	(11.9.7.5)	(oo oo oo ox xo xx)
201 x	+	+	(11.9.7.5)	(11.9.7.5)	(oo oo oo xx oo xx)
y	+	+	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xx rr)
218 x	+	+	(9.8.5.3)	(9.8.5.3)	(oo oo oo oo rr oo)
y	+	+	(7.5.5.3)	(7.5.5.3)	(oo oo oo oo xx oo)
233 x	+	+	(7.5.5.3)	(7.9.7.5)	(xx xx oo xx xx oo)
y	+	+	(7.5.5.3)	(10.9.6.5)	(oo oo oo ox xo oo)
274 x	+	+	(11.0.7.5)	(11.0.7.5)	(oo oo oo oo oo xx)
y	+	+	(11.0.7.5)	(11.0.7.5)	(oo oo oo oo oo xx)
301 x	+	+	(9.0.5.5)	(11.0.7.5)	(oo oo oo oo oo rr)
y	+	+	(8.7.10.5)	(11.0.7.5)	(oo oo oo oo xo rr)
304 x	+	+	(7.0.5.4)	(7.5.5.4)	(oo oo oo oo ox rx)
y	+	+	(7.5.5.4)	(11.9.7.5)	(oo oo oo ox xo rx)
306 x	+	+	(9.7.5.5)	(9.7.5.5)	(oo oo oo oo xx rr)
y	+	+	(7.5.5.5)	(11.8.7.5)	(oo oo oo oo xo rr)

MENTAL AND PHYSICAL TRAITS

Younger versus older twins

The argument that older twins show no greater degree of similarity than younger twins, and that, hence, nature is more potent than nurture, was first advanced by GALTON (1883). Since that time other evidence to substantiate his theory has been presented by THORNDIKE (1905) and MERRIMAN (1924). GALTON'S conclusions were based on verbal reports and cannot be objectively stated. THORNDIKE'S coefficients for younger twins (9 to 11 years) averaged 83; for older twins (12-14 years) 70. MERRI-

MAN in his study was able to take much more adequate measurements due to the development of standardized tests. His coefficients for younger twins (5 to 9 years) averaged 77; for older twins (10 to 16 years) 67. The results of my study are given in table 13.

The evidence, though somewhat variable, is, nevertheless, conclusive. Even the averages in each case reveal no greater similarity among the older twins than among the younger twins. THORNDIKE concludes, with reference to his data, that the most probable explanation of differences is chance. MERRIMAN reaches the same conclusion. An inspection of my data shows that even in traits most subject to training there are no large differences. One might expect greater similarities in reading, arithmetic and writing, abilities subject to training, but such similarities do not materialize except in reading.

TABLE 13

Older versus younger twins. About 100 cases in each group.

TRAIT	90 to 156 MONTHS	157 to 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

Like-sex versus unlike-sex twins

Neither THORNDIKE nor GALTON report any studies of the differences in mental traits between like- and unlike-sex pairs of twins. The only adequate data available are those of MERRIMAN (1924, p. 29) which are given in table 14.

TABLE 14

Like- versus unlike-sex twins (MERRIMAN).

TEST	LIKE-SEX	UNLIKE-SEX	DIFFERENCE
Stanford-Binet (intelligence quotients)	.867	.504	.363
Army Beta (intelligence quotients)	.908	.732	.176
National Intelligence Test (intelligence quotients)	.925	.867	.058
Teacher estimates	.654	.266	.388
Averages	.838	.592	.246

MERRIMAN offers his results as evidence favoring the theory of two types of twins, one-egg and two-egg. It seems logical to suppose that the twins derived from a single germ should be more nearly alike than those derived from two separate germs and since the one-egg twins are included in the like-sex group, the higher correlation is attributed to the circumstance of origin. MERRIMAN'S distribution of intelligence-quotient differences points in the same direction.

My own data make it possible to secure three groupings according to sex. It will be seen that my results corroborate those of MERRIMAN. In general intelligence, memory for digits, and speed in handwriting, the differences between the abxy and ax pairs is marked. In reading, an ability much subject to training, there is only a slight difference, while in arithmetic the difference is considerable.

TABLE 15

Like- versus unlike-sex twins. About 70 cases in each group.

TRAITS	AB	XY	AVERAGE	AX	DIFFERENCE
Intelligence quotients	81	73	77	56	+21
Reading quotients	62	56	59	56	+03
Arithmetic, accuracy	72	65	69	35	+34
Arithmetic, speed	70	69	70	39	+31
Addition, accuracy	66	35	51	34	+17
Addition, speed	65	56	61	40	+21
Subtraction, accuracy	65	63	64	44	+20
Subtraction, speed	69	51	60	23	+37
Multiplication, accuracy	48	32	40	09	+31
Multiplication, speed	60	39	50	25	+25
Division, accuracy	07	06	07	09	−02
Division, speed	55	64	60	30	+30
Memory for digits	44	36	40	25	+15
Handwriting, quality	69	68	69	37	+32
Handwriting, speed	82	84	83	37	+46
Averages	61	53	57	33	+24

In general, then, like-sex pairs of twins show greater similarities than unlike-sex pairs. It should be noted, however, that the very circumstance of sex tends to vary environment and the older the twins become the greater the environmental difference. A boy and a girl brought up in the same home are not in the same environment. Almost from birth the environment of the girl has been different from that of the boy, even under the same parental roof. While I see no method of eliminating these factors from my data, they do exist and may have an important bearing on twin resemblances. The fact is well attested by the evidence

that like-sex pairs of twins show a greater degree of intellectual resemblance than unlike-sex pairs of twins, and it is probable that these differences exist by virtue of original nature, since environments which seem to be similar have little influence in modifying the relationships.

Twins versus other sibs

Several studies have been made of sib resemblance, all with essentially the same result. PEARSON'S (1904) data are frequently quoted. His correlation coefficients average for the brother-brother data, 52; for the sister-sister, 61; and for the brother-sister, 52.

Miss EMILY DEXTER (1915) of the UNIVERSITY OF WISCONSIN made a study of sib resemblance based on data collected on approximately 184 brothers and sisters in the UNIVERSITY OF WISCONSIN and on about 69 high-school students. In table 16 correlation coefficients in English, language, mathematics, history and science are given. In the same manuscript Miss DEXTER reports the following correlations in general intelligence, the data used being based on intelligence quotients and coefficients of brightness obtained on the Dearborn Test and the National Intelligence Test given to about 800 children in the elementary schools of Madison, Wisconsin (see table 17).

TABLE 16

Sib resemblance in scholarship (DEXTER).

GROUPS	SCHOLARSHIP AVERAGE	ENGLISH	LANGUAGE	MATHEMATICS	HISTORY	SCIENCE
University						
All pairs	34	28	23	07	29	20
Brother-brother	40	14	20	05	35	31
Sister-sister	34	50	34	03	21	15
Brother-sister	32	02	07	07	26	21
High-school						
All pairs	28	23	09	19	33	35

TABLE 17

Sib resemblance in general intelligence (DEXTER).

GROUPS	GROUP 1	GROUP 2	GROUPS 1+2	GROUP 3
All pairs	53	45	49	61
Brother-brother	55	49	53	66
Sister-sister	42	38	40	52
Brother-sister	54	46	51	63

From an inspection of these studies it is apparent that sib resemblance is approximately 50. It has already been seen from data presented that THORNDIKE places twin resemblance at 80. MERRIMAN places it at the same figure for like-sex pairs, but finds a twin resemblance of about 60 for unlike-sex pairs. The average of all traits in the like-sex twins in my study is approximately 55; while that for unlike-sex twins is approximately 30. In general intelligence and handwriting my figures more nearly approximate the commonly accepted 80 for like-sex pairs and 50 for unlike-sex pairs. But regardless of the lower average figure, the difference in correlation between like- and unlike-sex pairs is still large.

Thus, the evidence all tends in the same general direction. Unlike-sex pairs of twins show a degree of resemblance about equal to that of other sibs, while like-sex pairs show a correlation considerably higher. The degree of resemblance between father and son, based on findings of ELDERTON (1907) and others, may be said to be about 40 and that for cousins, 25. We have, then, a chain of evidence as follows:

Like-sex twins	80
Unlike-sex twins	50
Other sibs	50
Parent-child	40
Cousins	25

The apparent conclusion is that the closer the relationship, the greater the resemblance. Unlike-sex pairs of twins approximate the resemblance of other sibs. This is what is naturally expected if two ova are fertilized by two separate sperm. The twins, to all intents and purposes, bear to each other a fraternal relationship. Then, if all twins are of two-egg origin, the correlation coefficients for like- and unlike-sex pairs should be approximately the same. The rather marked difference, however, which the facts reveal, has been attributed by most investigators to a difference in origin, that is, approximately one-half of all like-sex pairs are of one-egg origin and therefore resemble each other more than the twins of two-egg origin. If the one-egg group of like-sex twins could be separated from the two-egg group, we would probably have in the former case a correlation approximating 90; in the latter case, a correlation approximating 50.

Native versus acquired traits

While environment seems impotent to change the general intellectual resemblance of twins, the evidence on traits much subject to training is

somewhat conflicting. The significant fact is that coefficients for multiplication, and particularly for division, are much lower than for addition and subtraction. It is in addition and subtraction that the twins have had most

TABLE 18

Twin resemblance in the fundamental processes of arithmetic (about 70 cases in each group except in division, where the number of cases is about 50 for each group.)

A. Accuracy

PAIRS	ADDITION	SUBTRACTION	MULTIPLICATION	DIVISION
ab	66	65	48	07
xy	35	63	32	06
ax	34	44	09	09

B. Speed

ab	65	69	60	55
xy	56	51	39	64
ax	40	23	25	30

training, they have had less in multiplication; and in the lower grades, very little in division. In fact, in some schools long division had not been taught when the tests were given. In addition and subtraction the individual's performance has been stabilized by practice. In multiplication and division his performance is still exceedingly variable, and as a consequence measurements of his ability are unreliable. The coefficient of correlation does not express the true relationship. The variability in performance and the consequent difficulty in measuring the true ability probably account for the lower correlations in multiplication and division.

Handwriting is an ability much subject to training. Yet here the effect of training is not at all clear:

Pairs	*Quality*	*Rate*
Younger pairs	49	66
Older pairs	58	55

In speed, training seems to make twins more unlike, while in quality the opposite is the case. The data may not, however, reveal the essential facts. In school, training in handwriting has usually ceased by the time the ninth grade is reached. It seems to be the general situation that the effects of training are rapidly lost. If the degree of resemblance could be determined for successive age groups, from the time that training begins until after it ceases, it seems reasonable to suppose that we would find

similarities increasing with training, probably within limits determined by sex and original nature.

In this connection it is interesting to note the varying degrees of resemblance in handwriting which have been reported, both in the case of twins and of other sibs. GALTON (1883, p. 157) says,

"Most singularly, the one point in which similarity is rare is handwriting. I cannot account for this, considering how strongly handwriting runs in families, but I am sure of the fact. I have only one case in which nobody, not even the twins themselves, could distinguish their own notes of lectures, etc.; barely two or three in which the handwriting was undistinguishable by others, and only a few in which it was described as closely alike. On the other hand, I have many in which it is stated to be unlike, and some in which it is alluded to as the only point of difference. It would appear that the handwriting is a very delicate test of difference in organization—a conclusion which I commend to the notice of enthusiasts in the art of discovering character by the handwriting."

In contrast to this conclusion, my own results are quite revealing. The data upon which these correlations were computed were secured from the handwriting of 200 pairs of twins measured by the Kansas City Handwriting Scale. Each specimen was scored by three competent judges,

TABLE 19

Resemblance in the handwriting of twins.

GROUP	QUALITY	SPEED
ab	69	82
xy	68	84
ax	37	37
Younger	49	66
Older	58	55

twice by judge A, and once each by judges B and C. The reliability coefficients of the judgments vary from 81 to 92, showing a rather high consistency in the four judgments (KRAMER 1924). It is safe to say from this study that the degree of resemblance in the quality of the handwriting of twins as measured by the Kansas City Scale is, for like-sex pairs, 70; for unlike-sex pairs, 40. In speed it is, for like-sex pairs, 80; for unlike-sex pairs, 40.

It should be noted, however, that quality alone, as measured by a scale, does not determine similarity. This is well illustrated by plate 4. These specimens receive average scores of 10.00 and 10.25 on the Kansas City Scale (four expert judges) and yet there would not be the slightest danger

HANDWRITING

These two specimens of the handwriting of a pair of twins were scored 10.25 and 10.00 by four judges on the Kansas City Handwriting Scale. While apparently very similar in quality they are markedly different in appearance.

SCORE: Rate 8.3 ... Quality 10.25 No. 290-a

If there is a ten minute period for writing drill as little time as possible should be spent in getting ready and in putting away materials. If there is a ten minute period for a little writing drill as little

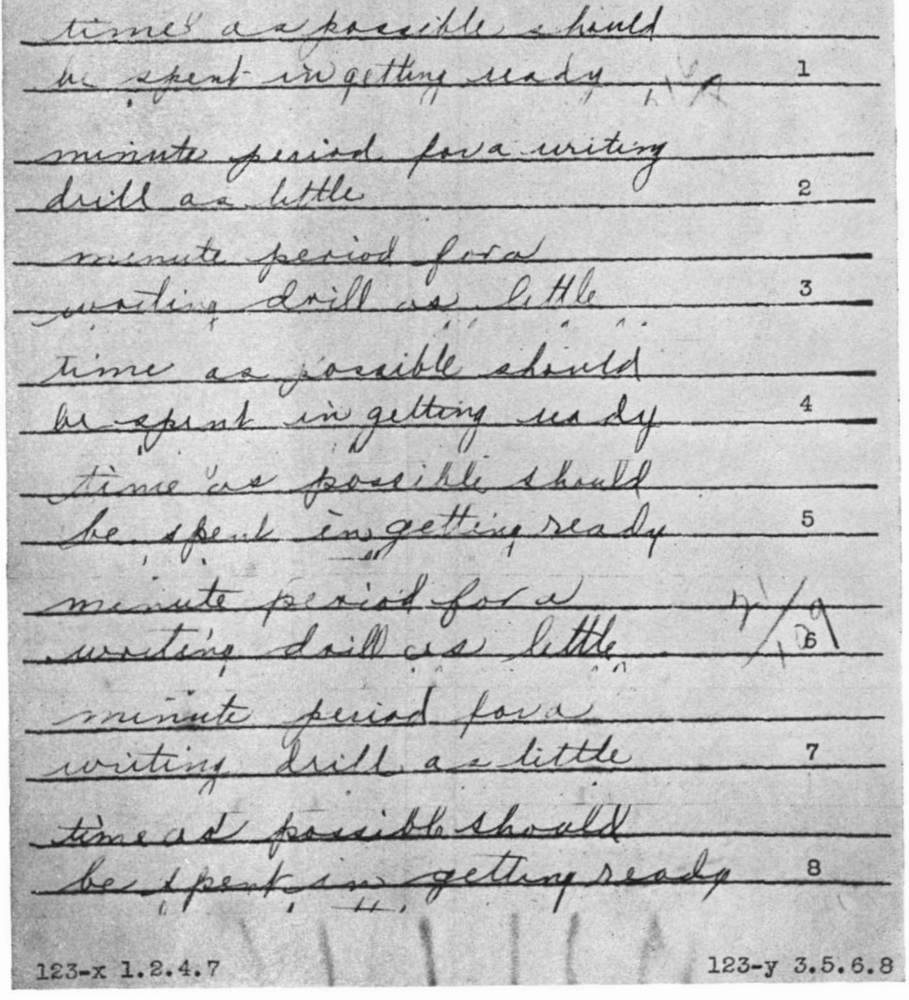
11.5

SCORE: Rate 11.5 ... Quality 10.00 No. 290-X

If there is a ten minute period for a writing drill as little time as possible should be spent in getting ready and in putting away materials. If there is a ten minute period for a writing drill as little time as possible should be spent in getting ready and putting away material

HANDWRITING

Below is shown the handwriting of a pair of girl twins (pair 123 xy) 199 months of age. These samples are very much alike, as is evidenced by the fact that they were given the same score on the Kansas City Handwriting Scale by four independent judges. Each sample was cut into strips and the strips were then pasted in mixed order on the sheet from which this photograph was made. The striking similarity between the two writings can be demonstrated by trying to pick out the lines that belong together. The correct combinations are given at the bottom of this page.



123-x 1.2.4.7 123-y 3.5.6.8

of mistaking one for the other. On the other hand the specimens of plate 5 are so nearly alike that a careful study of the peculiarities of letters is necessary before one specimen can be distinguished from the other. Similarity in appearance is largely determined by such obvious characteristics as size and shape of letters, boldness of stroke, and slant, and not by the more subtle characteristics of "quality." GALTON'S conclusion, based on the test he applied, is probably correct. On the other hand the degree of resemblance, measured in terms of quality and speed, is much higher than his conclusions might lead one to believe.

PEARSON (1904) found resemblance in handwriting of sibs to be 52. STARCH (1917) has reported two studies with widely varying results:

	1915	*1917*
Quality	06	46
Speed	18	72

The 1915 study was based on 24 pairs of sibs; the 1917 study, on 18 pairs. One fact in STARCH'S results and my own may be pointed out, namely, that if unlike-sex twins represent a fraternal relationship, then STARCH'S coefficients of correlation in the 1917 study and my own are in practical agreement as far as quality is concerned. But in speed, STARCH'S coefficient exceeds the usual coefficient of sib resemblance.

Data	*Quality*	*Speed*
STARCH (single-birth sibs)	46	72
LAUTERBACH (unlike-sex twins)	37	37

In memory for digits the evidence is clear; but in intelligence quotient and reading quotient the older twins show a slightly closer resemblance than the younger. A summary of the evidence would seem to indicate that training has very little effect either upon native or acquired traits.

TABLE 20

Resemblance in general intelligence, reading and memory for digits.

GROUP	INTELLIGENCE QUOTIENT	READING QUOTIENT	DIGITS
Younger pairs.....	64	44	36
Older pairs.....	73	57	34

The intellectual level of a twin population

The intellectual level of a twin population was first investigated by MERRIMAN (1924), who made a comparison (table 21) of the intelligence quotients of about 200 pairs of twins with the intelligence quotients of

TABLE 21

The average intelligence quotients of various groups of twins (MERRIMAN).

GROUP	FREQUENCY	AVERAGE INTELLIGENCE QUOTIENT
All twin pairs	105	96
Pairs 5 to 9 years old	47	99
Pairs 10 to 16 years old	58	94
Like-sex pairs	67	97
Like-sex pairs 5 to 9 years old	29	99
Like-sex pairs 10 to 16 years old	38	95
Unlike-sex pairs	38	95
Unlike-sex pairs 5 to 9 years old	18	98
Unlike-sex pairs 10 to 16 years old	20	92
Girl-girl pairs	40	94
Girl-girl pairs 5 to 9 years old	19	99
Girl-girl pairs 10 to 16 years old	21	90
Boy-boy pairs	27	100
Boy-boy pairs 5 to 9 years old	10	99
Boy-boy pairs 10 to 16 years old	17	101
Boys of unlike-sex pairs	38	95
Girls of unlike-sex pairs	38	95

905 unselected children reported by TERMAN (1916). There are no significant differences between my own results (shown in table 22) and those of MERRIMAN. My age range is from 90 months to 238 months and all ages

TABLE 22

The average intelligence quotients of various groups of twins

GROUP	FREQUENCY	AVERAGE INTELLIGENCE QUOTIENT
Boy-boy pairs	70	94
Girl-girl pairs	75	94
Boy-girl pairs	63	97
Younger pairs	108	98
Older pairs	98	93
Like-sex pairs showing symmetry reversal	36	95
Unlike-sex pairs showing symmetry reversal	27	99
Boy-boy pairs, symmetry reversal pairs omitted	48	94
Girl-girl pairs, symmetry reversal pairs omitted	61	95
Unlike-sex pairs, symmetry reversal pairs omitted	34	95

have been included in the calculations. MERRIMAN kept his groups within the range of 5 to 14 years to compare with the TERMAN data on unselected children. The data are therefore perhaps not quite comparable. But the older twins should have had the advantage in the TERMAN group test and their scores probably run somewhat high. At least they do not overemphasize the facts in the direction of low intelligence. The two sets of averages are quite consistent.

MERRIMAN concluded that a twin population suffers no intellectual handicap. To further test his data, he made a frequency distribution of the intelligence quotients of his 200 pairs of twins in comparison with a similar distribution of the intelligence quotients of TERMAN'S 905 unselected children. In figure 3 all three groups of data are plotted. In spite of the fact that the average intelligence quotient in each case closely approximates the average of the unselected group of children, it will be seen that a considerable percentage of the twins falls below the average of the unselected group.

However, a most striking situation is revealed when my group of twins is distributed on an age-grade chart. The startling fact develops that 45.8 percent of all twins are retarded; 45.6 percent are normal and 8.6 percent are accelerated. Of the boys, 47.9 percent are retarded, 44.4 percent are normal and 7.7 percent accelerated. Of the girls, 43.8 percent are retarded, 46.7 percent are normal, and 9.8 percent are accelerated. The percentages are summarized for convenience in table 23.

TABLE 23

Age-grade distribution of 203 pairs of twins.

	BOYS		GIRLS		TOTALS	
	Number	Percent	Number	Percent	Number	Percent
Normal	87	44.4	98	46.7	185	45.6
Retarded	94	47.9	92	43.8	186	45.8
Accelerated	15	7.7	20	9.5	35	8.6
Totals	196	100.0	210	100.0	406	100.0

In the case of twins we actually have more retardates than normal pupils! Is this retardation to be attributed to a lower general intelligence level in the twin population?

An investigation of over-age children was made by the STATE DEPARTMENT OF EDUCATION in Wisconsin (RANKIN 1916) for the years 1913-14. The average percentage of retardates reported is 56.3; of accelerates, 12.2; of normal pupils, 31.5.

In progress in school the twins are on a par with the school population of which they are a part. There is no evidence, therefore, which warrants the assumption that the intellectual level of a twin population is lower than that of the population in general.

Characteristics of symmetry-reversal groups

It is of interest to note the resemblance, both mental and physical, of the group of twins which manifest symmetry reversal in handedness and

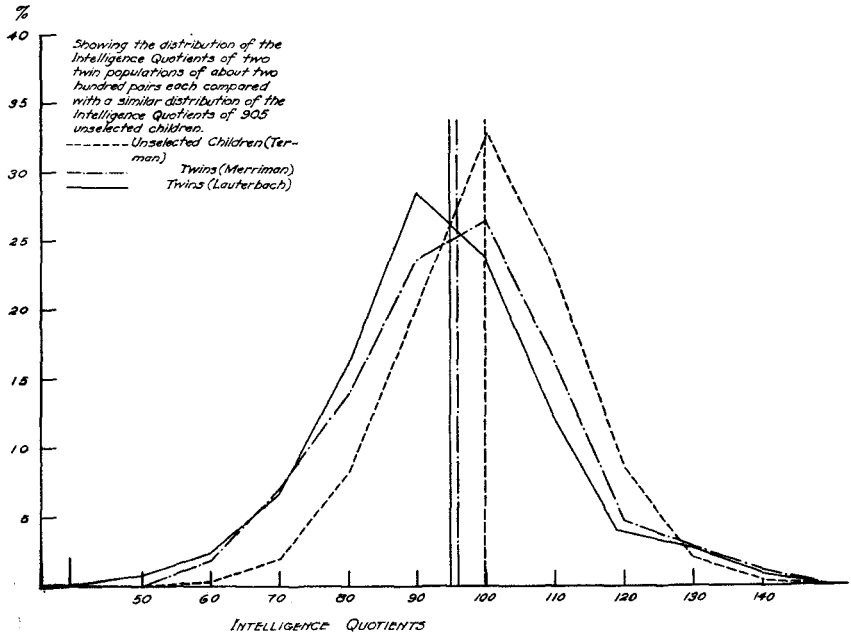


FIGURE 3

whorl of the head-hair. These resemblances are shown in table 24. Theoretically, if symmetry reversal is an indication of the one-egg origin of twins, these groups ought to be more nearly alike than any others. But the data reveal almost the opposite case. In physical traits this disparity is most striking.

Here the average of the coefficients drops from .77 for the abxy group to .59, when only the members of the abxy group which show symmetry reversal are taken. If there are two types of twins, similarity or dissimilarity seems to offer no clue for the identification of either group and symmetry reversal certainly adds nothing to clarify the situation.

TABLE 24

Coefficients of correlation in traits of the symmetry-reversal (SR) groups as compared with the abxy and the ax groups.*

TRAIT	ABXY	ABXYSR	AX	AXSR
Intelligence quotients	.77	.77	.56	.59
Reading quotients	.59	.65	.56	.69
Arithmetic, accuracy	.69	.61	.35	.19
Arithmetic, speed	.70	.73	.39	.25
Memory for digits	.40	.31	.25	.49
Handwriting, quality	.69	.65	.37	.41
Handwriting, speed	.83	.82	.37	.31
Averages	.67	.65	.41	.42
Cephalic index	.67	.73	.59	.49
Weight	.89	.65	.50	.53
Height, standing	.80	.54	.53	.44
Height, sitting	.73	.43	.59	.55
Averages	.77	.59	.55	.50

* SR stands for symmetry reversal. AbxySR means the group of like-sex twins showing symmetry reversal; axSR means the group of unlike-sex twins showing symmetry reversal.

Physical traits

THORNDIKE (1905) reports coefficients of correlation in physical traits of 31 pairs of twins which vary from 65 for finger-joint length to 83 for height sitting. He attacked the problem of two types of twins by figuring correlation coefficients for single pairs and then making a frequency distribution of these coefficients. The distribution shows a unimodal curve skewed toward the higher end of the scale.

TABLE 25

Resemblance in physical traits shown by coefficients of correlation

TRAIT	AB	XY	AX	YOUNGER	OLDER
Height, standing	.72	.87	.53	.61	.65
Height, sitting	.70	.76	.59	.60	.58
Weight	.93	.85	.50	.59	.64
Cephalic index	.63	.71	.59	.72	.61
Averages	.75	.80	.55	.63	.62

Correlations computed by myself on data collected on 200 pairs of twins are recorded in table 25. A study of the table reveals at once the striking difference in degree of resemblance between like-sex pairs and

TABLE 26

Summary table of correlation coefficients and probable errors. Age held constant.

TRAIT	AB	XY	AX	ABXYSR	AXSR	YOUNGER	OLDER
Intelligence quotients	.81 ± .03	.73 ± .04	.56 ± .06	.77 ± .05	.59 ± .06	.64 ± .04	.73 ± .03
Reading quotients	.62 ± .05	.56 ± .05	.56 ± .06	.65 ± .06	.69 ± .07	.44 ± .05	.57 ± .05
Arithmetic, accuracy	.72 ± .06	.65 ± .07	.35 ± .08	.61 ± .07	.19 ± .13	.59 ± .04	.50 ± .05
Arithmetic, speed	.70 ± .06	.69 ± .06	.39 ± .07	.73 ± .06	.25 ± .12	.59 ± .04	.57 ± .05
Addition, accuracy	.66 ± .05	.35 ± .07	.34 ± .08				
Addition, speed	.65 ± .05	.56 ± .06	.40 ± .07				
Subtraction, accuracy	.65 ± .05	.63 ± .05	.44 ± .07				
Subtraction, speed	.69 ± .04	.51 ± .06	.23 ± .08				
Multiplication, accuracy	.48 ± .06	.32 ± .07	.09 ± .09				
Multiplication, speed	.60 ± .05	.39 ± .07	.25 ± .08				
Division, accuracy	.07 ± .09	.06 ± .05	.09 ± .09				
Division, speed	.55 ± .06	.64 ± .02	.30 ± .09				
Memory for digits	.44 ± .07	.36 ± .07	.25 ± .08	.31 ± .10	.49 ± .09	.36 ± .06	.34 ± .06
Handwriting, quality	.69 ± .04	.68 ± .04	.37 ± .08	.65 ± .07	.41 ± .10	.49 ± .05	.58 ± .05
Handwriting, speed	.82 ± .03	.84 ± .02	.37 ± .08	.82 ± .04	.31 ± .11	.66 ± .04	.55 ± .05
Height, standing	.72 ± .06	.87 ± .03	.53 ± .07	.54 ± .08	.44 ± .10	.61 ± .04	.65 ± .04
Height, sitting	.70 ± .06	.76 ± .05	.59 ± .06	.43 ± .09	.55 ± .09	.60 ± .05	.58 ± .05
Weight	.93 ± .02	.85 ± .03	.50 ± .07	.65 ± .07	.53 ± .09	.59 ± .05	.64 ± .04
Cephalic index	.63 ± .05	.71 ± .04	.59 ± .06	.73 ± .05	.49 ± .09	.72 ± .03	.61 ± .05

unlike-sex pairs. The difference is most marked in weight and least marked in cephalic index. It is probable, however, that these differences can be attributed to sex.

Maturity seems to have no influence on the degree of resemblance among twins, since the data on the older twins yield approximately the same coefficients of resemblance as data on the younger twins.

CONCLUSIONS

1. Older twins show no greater degree of resemblance than younger twins. This is in conformity with the findings of THORNDIKE (1905) and MERRIMAN (1924), and favors the argument that heredity is more potent than environment.

2. Like-sex pairs of twins show a greater degree of resemblance than unlike-sex pairs. These differences in degree of similarity are attributed by MERRIMAN to the circumstance of origin (monozygotic or dizygotic). The facts seem to favor the theory.

3. Twins show a greater degree of resemblance than other sibs. It has also been shown that single-birth sibs are more nearly alike than parents and children; and parents and children, than cousins. The inference follows that the closer the relationship, the greater the resemblance.

4. Unlike-sex pairs of twins show a degree of resemblance about equal to that of single sibs. A fraternal relationship is thus indicated.

5. There seems to be no definite tendency among twins toward greater similarity in acquired traits than in native ability. The evidence is somewhat conflicting, a fact noted by THORNDIKE.

6. There is no evidence which warrants the assumption that twins are intellectually handicapped. MERRIMAN also presents data which seem to favor a normal intellectual level in the twin population.

7. About twenty percent of all twin pairs show symmetry reversal in handedness.

8. About twenty-five percent of all twin pairs show symmetry reversal in whorl of the head-hair.

9. About thirty-five percent of all twin pairs show symmetry reversal in handedness or whorl of the head-hair or both.

10. Symmetry reversal cannot be accepted as evidence of the monozygotic origin of twins, for the reason that unlike-sex pairs as well as like-sex pairs manifest the phenomenon. NEWMAN and WILDER advance the theory that symmetry reversal is an evidence of the monozygotic origin of human twins. The facts will not substantiate the theory unless the possibility is admitted that monozygotic twins may be of unlike sex.

11. Left-handedness is closely associated with twinning. This is evidenced by the large number of twins who are left-handed, by a study of the genealogies of twin-bearing families, and by the circumstance of "situs inversus viscerum "among both twins and left-handed individuals.

12. It may be that left-handedness and twinning are the result of identical or similar causes. This inference rests on the apparent intimate connection betweem left-handedness and twinning.

13. Palm patterns afford no certain means of identifying monozygotic twins. Unlike-sex pairs of twins may show identity of palm patterns and reveal symmetry reversal.

For the sake of completeness there may be added certain conclusions deduced from other evidence.

14. The monozygotic origin of quadruplets among armadillos has been established by NEWMAN. By analogy, twins among other vertebrates, including man, may have a similar genesis.

15. The dissection of conjoined twins, and X-ray examinations of their anatomy, favors the theory of the monozygotic origin of twins by fission in the fertilized ovum.

16. An examination of the foetal membranes of twins at birth has frequently revealed a single placenta and a single chorion. Biologists

maintain that such a condition is the result of genesis from a single ovum.

17. Sex ratios among twins favor the theory of two types of twins the actual ratio being approximately 1 : 1 : 1, whereas, if there were only one type, it ought, by the law of chance, to be approximately 1 : 2 : 1.

18. MERRIMAN has shown statistically that a distribution of the intelligence quotients of a twin population represents two types of population and he concludes that these two types are determined by one-egg and two-egg genesis.

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