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THE GENETIC DETERMINATION OF DIFFERENCES IN INTELLIGENCE: A STUDY OF MONOZYGOTIC TWINS REARED TOGETHER AND APART

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In the course of a series of investigations into various aspects of mental inheritance an intensive study has been made of so-called 'identical' twins. The cases examined fall into two main groups: first, those reared together in their parents' homes; secondly, those separated in early infancy, and brought up apart. With the latter, despite wide differences in environmental conditions, the correlations for intelligence, unlike those for school attainments, prove to be surprisingly high. It is argued that this implies that 'intelligence', when adequately assessed, is largely dependent on genetic constitution. Supplementary correlations from other groups (dizygotic twins, siblings reared together and apart, first and second cousins, and other related pairs) confirm this conclusion.

I. The complexity of the problem

Individual psychology and psychogenetics might themselves be fairly described as fraternal twins: they were begotten by the same father, Sir Francis Galton, and they emerged almost simultaneously as vigorous offspring of the mother science. Unfortunately they became parted soon after birth. Consequently, as Professor Darlington has remarked in a recent paper (this *Journal*, 1963, p. 293), 'despite their common origin, psychology and genetics, whose business it is to explain behaviour, have failed to face their task together'. One reason suggested is that general psychology has so far been unable to supply the genetic psychologist with any clear conception of what is commonly called the mind, or of its structure and development, such as might serve as a working basis for his researches. He has therefore to shoulder the preliminary task of determining for himself what particular traits or tendencies he shall select for observation and assessment.

In the case of the human species the variations with which the student of individual psychology is commonly concerned have proved to be extremely complex. In the first place, as Galton pointed out, a person's success in almost every walk of life depends on at least three distinguishable types of mental quality—cognitive, affective and conative: 'he must possess the requisite abilities; he must respond with eagerness and zeal; and he must sustain the necessary effort'. Secondly, statistical studies based on factorial techniques have demonstrated pretty clearly that we can no longer be content with the traditional notion of a motley assortment of cognitive 'faculties' or 'primary abilities', such as Thorndike at one time postulated and many educational and psychological writers still tacitly assume, nor yet with the oversimplified hypothesis of a single 'general factor' which Spearman proposed to substitute. The evidence—biological and neurological as well as purely statistical—suggests that the brain, or rather the central nervous system, is an organized hierarchy comprising both a 'general cognitive factor' and a number of more specialized 'group factors' of varying extent or breadth; but of these the 'general factor' is by far the most important, especially during early years. Thirdly, a vast mass of

evidence, which I have summarized in previous papers, suggests that differences in this factor are largely the effect of the individual's genetic constitution—the product of the particular set of genes which each pair of parents transmits to their offspring—and that the mode of transmission conforms to the general principles worked out by Mendel and his followers for unifactorial and multifactorial inheritance (Burt, 1912, 1958, and refs.).

This threefold distinction—between cognitive characteristics and motivational, between general characteristics and the more specialized, and between genetic characteristics and those that are acquired—leads to the concept of an 'innate, general, cognitive factor', each of the adjectives being defined in a somewhat technical sense. The problem for the psychologist therefore has been to decide, by means of appropriately planned research, whether such a factor really exists, and if so, what is its practical significance. To designate this concept it is more convenient to use one word instead of four, and Spencer's term 'intelligence' has been adopted (perhaps a little unwisely*) as a popular label. Differences in this hypothetical ability cannot be directly measured. We can, however, systematically observe relevant aspects of the child's behaviour and record his performances in standardized tests; and in this way we can usually arrive at a reasonably reliable and valid estimate of his 'intelligence' in the sense defined. But it is clear that what we thus observe or calculate is a somewhat artificial abstraction, and, developmentally at any rate, decidedly remote from the aggregate of biochemical tendencies transmitted at the time of sexual reproduction.

Of late, however, an increasing number of British psychologists and educationists have vigorously challenged, not so much the bare fact of mental inheritance, but the idea that it has any appreciable importance as compared with environmental influences. Most of their criticisms rest, not on any fresh evidence or new researches of their own, but chiefly on armchair arguments from general principles. There are two obvious ways in which the questions thus raised can be met and dealt with.

(1) First, we can compare the performances of children who *differ in their presumable inheritance*, but have been brought up in much the same environment—children, for example, who have been removed soon after birth to an orphanage or other institution. With the present problem largely in view, I and my colleagues under the London County Council carried out a series of investigations on such cases (Burt, 1943). Two main results emerged. (i) In spite of the uniformity of the environment, the individual variation in intelligence was at least as great as that of a random sample of children living in their homes. (ii) These variations showed a fairly close correlation (about 0·5), with the variations in the intelligence of their parents. Some of the most striking instances were illegitimate children of high ability; often the father (as the records showed) had been just a casual acquaintance of the mother, well above her own social and intellectual status, who had taken no further interest in the child, and whom the child himself had never even seen. In such a case it would be out of the question to attribute the child's exceptional intelligence to the cultural opportunities of his home, since his only home had been the institution to which he had been sent.

* How unwisely is shown by the use of the term in the recent correspondence in the *Listener* (24 June to 17 July 1965), which followed articles on mental inheritance by Dr Liam Hudson and Dr Hammerton. Almost everybody treated the word 'intelligence', not as a technical term, but as a word of popular speech to be interpreted according to the fancy of the writer.

(2) Secondly, however, we may compare the performance of children who have the *same genetic constitution*, but have been brought up in widely different environments. Galton (1883) was apparently the first to recognize that the occurrence in man of so-called 'identical' twins 'makes it possible to show, more clearly than in other animals, the relative influence of differences in genotype and in environment respectively' (Darlington & Mather, 1949, p. 349). 'Monozygotic' or 'uniovular' twins are derived from the splitting of a single fertilized egg or zygote. Since they are developed from the same cell-nucleus, it follows that (barring accidents to the chromosomes, which are by no means unknown) they must have the same outfit of genes. However, the cytoplasm of the cell, as well as its nucleus, can occasionally influence heredity; and, unlike the splitting of the nucleus, the splitting of the cytoplasm could introduce a slight genetic difference (Spiegelman, 1946): hence the description 'identical' may be somewhat misleading. In the paper just quoted Darlington noted 'what an extraordinary success this [line of research] has had as a means of comparing the effects of a difference in heredity and in environment'; but he went on to warn the psychologist against the hasty inferences and simplifications often made in interpreting such data, not so much by Galton himself as by some of his over-enthusiastic successors.

In most of the investigations in which 'identical' twins have been distinguished from 'fraternal' the two members of each pair have nearly always been brought up together, usually in their own homes. Now it is well known that identical twins tend to keep together far more than fraternal twins, particularly since about half the fraternal twins are of different sex. The environmentalist therefore naturally argues that the higher correlation for intelligence found in the case of identical twins can be fully explained by the greater similarity in their life-histories. To meet this criticism my co-workers and I decided to make a special study of cases in which the members of such pairs had been brought up in entirely different environmental conditions.

In our earliest survey of children in L.C.C. schools and institutions we reported a number of case-studies in which 'identical' twins had been separated during the first few months of life (Burt, 1921 and refs.); and over the years the number has steadily increased. Other writers, chiefly geneticists, have described isolated instances in which the members of a single pair were reared apart: of these the earliest is perhaps the most instructive (Popenoe, 1922; cf. Muller, 1925). Three group-studies, in addition to our own, have since been published (Newman, Freeman & Holzinger, 1935; Juel-Nielsen & Mogensen, 1957; Shields, 1962); and the total number thus investigated now amounts to well over hundred. Strange to say, however, apart from our own, nearly all the inquiries have been concerned, not so much with children, but with adults; and for adults of course it is far more difficult to secure complete or accurate data.

During the last 10 years or so the inferences drawn from these and similar studies have been repeatedly questioned by several writers, both in this *Journal* and elsewhere—notably by Halsey (1959), Stott (1956), Lewis (1957), Maddox (1957) and Woolf (1952). The most recent and the most outspoken is McLeish (1963). He cites and criticizes the work both of Newman and myself. The correlations obtained, so he tells his readers, show that 'identical twins reared apart resemble each other on intelligence tests about as much as do fraternal twins reared together'; (this is by no

means accurate as a glance at the figures will show; see Table 2). At all events, he says, 'the best studies' (which these are he does not specify) 'render the initial assumptions of the tester obsolete or highly questionable'; and the idea that 'identical twins are endowed with the same genes' is itself 'an assumption open to question' (on what grounds we are not told).

On the other hand, Shields (1962) has recently reached conclusions which are much the same as my own. In his review of 'previous reports' he refers to a war-time paper of mine on 'Ability and income', in which I quoted data from our first London survey (Burt, 1921), and included correlations between children related in various degrees (including a small group of monozygotic twins reared apart) whose after histories had been followed up for 15–20 years (Burt, 1943). He regrets that I have 'given no other information about the twins brought up apart'. The paper which he cites, however, was concerned primarily with the 'influence of innate ability and parental income on entrance to universities', and the mention of twins was merely incidental. For further information I expressly referred to previous L.C.C. Reports, and explained that my own research students were still 'working on data obtained for twins up to the outbreak of the war'. After the war a fuller account was printed in the same journal (Burt, 1955), and the statistical evidence set out in some detail by my co-workers and myself in one of the more technical periodicals (Burt & Howard, 1957; Conway, 1958). Both the earlier and the later publications, however, seem to have escaped Dr Shields's attention.

Meanwhile, largely as a result of these various discussions, further cases of separated twins have been brought to our notice, and more information has now been obtained for the earlier cases from the follow-up inquiries. The main purpose of the present paper therefore will be to bring together the evidence now available both from our studies and those of more recent investigators, and at the same time to answer the questions and criticisms raised by Dr Shields, Dr McLeish, and other writers.

II. DATA ON TWINS REARED APART

The tests employed have been fully described elsewhere (Burt, 1921, 1933). Except for three children living in rural areas who had to be visited during the holidays, all the tests were applied in school. They consisted of (i) a group test of intelligence containing both non-verbal and verbal items, (ii) an individual test (the London Revision of the Terman–Binet Scale) used primarily for standardization, and for doubtful cases (iii) a set of performance tests, based on the Pintner–Paterson tests and standardized by Miss Gaw (1925). The test-results, which generally covered other children in the school as well, were submitted to the teachers for comment or criticism; and, wherever any question arose, the child was re-examined. It was not practicable for the same person to test every child. I was helped by three principal assistants, and in a few cases by research-students, all of whom had been trained by me personally. The methods and standards therefore remained much the same throughout the inquiry. If any divergence occured, it would tend to lower rather than to raise the correlations. The reliability of the group test of intelligence was 0·97; of the Stanford–Binet 0·95; of the performance tests 0·87. For school attainments we used the group tests constructed and standardized for London children

(Burt, 1921). Assessments of eye-colour, head-length, and head-breadth were obtained for all twins, but only random samples (fifty of each sex) in the case of the ordinary siblings: measurements for height and weight were corrected for sex and age.* The number of children in each of the categories to be compared is shown at the top of each column in Table 2.

Most writers (e.g. Shields, 1962, pp. vi, 9) apparently suppose that 'monozygotic twins who have been separated from early childhood are of great rarity'. This we believe to be founded on a misconception. At the time of our main survey the number of twins among children born in London (excluding those who were not British) amounted to 1·4%; and of these nearly a quarter must have been monozygotic. This follows because among twins generally about 38% are of unlike sex; and among dizygotic twins the number of pairs of like sex must be approximately equal to the number of unlike sex. Monozygotic pairs are always of the same sex. Hence about $100 - 2 \times 38 = 24\%$ of all twins must be monozygotic. Twins brought up together usually attend the same or neighbouring schools; and, even after full allowance has been made for the higher mortality of twins during pre-school years, the proportion discoverable by school visiting alone is far less than would be expected from the number of those born. What happens is fairly clear. Many mothers are unable or unwilling to rear two children at the same time; but they are generally reluctant for it to be known that they have arranged for one of the children to be removed at or soon after birth. Since the actual placements are often carried out by the local authority or by some public body, a psychologist or social worker who is also a member of the staff can usually obtain full particulars for a large number of such cases. Hitherto most of the published researches have been undertaken by outside investigators who have no access to these confidential records. May we therefore urge that other educational psychologists, who have the advantage of being on the staff of a local authority, should conduct similar inquiries along much the same lines?

From Table 2 it will be seen that the number of monozygotic pairs we have studied now amounts to 148, of whom fifty-three have been reared apart. Of the ninety-five pairs who were reared together, the majority attended London schools; thirty-seven came from areas outside London: nearly half of these were encountered during an investigation I was asked to carry out for the Birmingham Education Authority; several were discovered in the Warwickshire area, where my family lived; and the rest were cases to which our attention was drawn by colleagues or correspondents. In each of the fifty-three pairs reared apart one child at least was a Londoner in all but eight cases. All had been separated either at birth or during their first six months of life. (In our initial report we included three who were separated considerably later; but they were subsequently omitted).

To determine 'zygosity', i.e. to distinguish 'identical' from so-called 'fraternal' twins, no one criterion is sufficient. A difference of sex is of course decisive; such a

* In the initial survey a few of the children living outside London were originally tested by the local teacher or school doctor; but these have all been since re-tested by Miss Conway. I should like once again to express my indebtedness to all who have assisted in this way, particularly to my former assistant Miss V. G. Pelling (who helped with the earlier surveys until her untimely death), to Miss Molteno, Mr Lewis, Miss Howard, and Miss Conway, as well as the various teachers and school doctors who frequently supplied physical and medical data.

pair cannot be monozygotic. With the younger children, particularly those born in the area in which the investigator was working, we were frequently able to secure detailed records of the mother's pregnancy and birth; and it is generally agreed that twins reported as born in a single chorion are monozygotic. When twins brought up together can be seen side by side, the impressionistic judgement of an expert observer is likely to be correct in nineteen cases out of twenty; but a few dizygotic twins are remarkably alike. Height, weight, and right- or left-handedness are unreliable; hair-colour, eye-colour, fingerprints and palm prints are more helpful. In doubtful cases the most valuable check is provided by an investigation of blood groups and serum groups. This had not been introduced when we started our inquiries; and, though in half-a-dozen of our later cases where slight doubts existed, it was adopted as an extra precaution, we were unable to carry it out as a routine procedure. We think it highly unlikely that any misclassifications have been made; but, if they have, their effect would be to reduce the differences between the correlations for monozygotic and dizygotic pairs. (See Essen-Möller (1941) and Penrose & Smith (1955) for a discussion of the peculiar methodology of the problem.)

One argument often advanced by our critics is that, although our separated pairs may have had a different environment from the day of birth or shortly afterwards, they must have had 'the same pre-natal environment, equally favourable in some cases, equally unfavourable in others'. But this, if correct, would apply to dizygotic twins almost as strongly as to monozygotic twins: the mere fact that the latter are enclosed in the same membrane, as well as in the same uterus, could not of itself account for the far higher correlations they provide. However, the assumptions on which the argument rests are not borne out by the actual facts. To begin with, the position of the foetuses within the uterus, and the time (and often the mode) of delivery will be different. Moreover, the immediate cause of the twinning process appears in most instances to be some temporary setback at the outset of gestation; and this may affect the different foetuses in different degrees. Before splitting the two portions of the developing embryo generally develop at different rates. When the splitting occurs at a fairly late stage, the twin derived from the less developed half tends to be both smaller and weaker. If the splitting occurs after the embryo has begun to assume bilateral symmetry, then, in certain anatomical details, one twin may even be the mirror image of the other. In conjoined or 'Siamese' twins, where the splitting occurs so late as to remain incomplete, reversals seem the rule rather than the exception. Among our own cases we noted that mirror reversals (opposite handedness, reversed patterns in finger-prints and palm-prints, contrary directions in the crown whorl of the hair, etc.) were nearly four times as frequent with monozygotic pairs as with dizygotic. It was among pairs in which, on these and other grounds, we inferred late splitting that we discovered the largest discrepancies in the estimates for intelligence; as a rule, the child delivered second turned out to be the feebler of the two both in mind and in physique: and, as gynaecological records show, it is the one most frequently still-born.

The biggest differences of all were found among low-grade mentally defective twins in L.C.C. instutitions. Here, out of twenty-six cases in which deficiency occurred in a monozygotic twin, there were twenty-one in which the other twin was *not* mentally deficient. These were likewise the cases in which physical differences were

most conspicuous. When the deficiency was of a high-grade type, unaccompanied by physical defect, both twins were commonly affected to much the same degree; and among those pairs in which the physical defect occurred in one twin only, the correlation between intelligence and the extent of the physical damage was decidedly low. We therefore concluded that intra-uterine conditions are, if anything, more likely to diminish the resemblance between twins than to increase it, and that, apart from the rare cases of marked pathological deficiency (not included in our present series), their effect on mental capacity is comparatively slight. (For fuller details see Burt & Howard (1956, pp. 123 f.) and references.)

In the records for our cases various reasons were given for the separation of the twins. In nine cases the mother had died either in childbirth or shortly afterwards; in the others the parents generally explained that they had felt unable to bring up both the children 'in a proper way'. In twelve the ground alleged was the mother's poor health; in six she was unmarried; in the remainder the chief or only ground was economic: e.g. the father was dead, out of work, or weak in health, and the mother was the main wage-earner; often, it was said, the family was already too large for the resources of the home; in the better classes the parents frequently declared that they could not afford the cost of educating both children in the way they deserved.

Since our object was to compare twins brought up in different environments with those brought up in similar circumstances, we included in our group of separated twins no cases in which both had been brought up by a relative, except for five in which one relative lived in a town and the other in the country. For our fifty-three separated cases the occupational categories of the parents and foster parents are shown in Table 1. The classification of occupations is the same as that adopted in my previous reports (for details see Carr-Saunders & Jones, 1937, pp. 55f.). The descriptions on the left indicate the occupational category of the children's own parents in cases where one child was brought up by them (the vast majority); in the few remaining cases that of the relative who adopted one of them, or the better type of foster-parent. These figures should dispose of one of the commonest explanations advanced by thoroughgoing environmentalists—namely, that the high correlations for the separated twins is due to the way the foster-parents were chosen.

Table 1. *Occupational categories of parents and foster parents*

		Foster parents							
	Parents	*I*	*II*	*III*	*IV*	*V*	*VI*	Residential institution	Total
I	Higher professional, etc.	0	0	0	1	2	0	0	3
II	Lower professional, etc.	0	0	1	0	4	2	2	9
III	Clerical, etc.	0	1	1	1	3	1	0	7
IV	Skilled	1	1	0	0	2	1	0	5
V	Semi-skilled	2	0	2	1	5	2	3	15
VI	Unskilled	1	1	0	0	7	3	2	14
	Total	4	3	4	3	23	9	7	53

Halsey (1959), for example, criticizes the inferences which my co-workers and I originally drew on two main grounds. First of all, he believes, the practice of 'selective placement' would suffice to account for the similarities found between twins who have been reared apart—an explanation also put forward by Hudson (1965).

Secondly, it is said, our cases 'do not represent the full range of the social and cultural scale'; hence the effects of environmental differences have not been allowed a fair opportunity to reveal themselves. Both criticisms are apparently derived from the notion that (as another critic has put it) 'official surveys confined to pupils in the ordinary elementary schools of the Council would not at that date have included children from the professional or well-to-do classes, nor those who are mentally deficient': with a wider range in the cultural background of the homes, so Dr Halsey maintains, we should have found a wider range in the children's intelligence; and in that case, particularly had defectives also been included, much larger discrepancies would have been discovered.

However, it can, I think, be safely stated that none of these objections is warranted. Had our critics referred to the original reports they would have seen that many of the children included among the twins reared apart were not in fact pupils at elementary schools. Three pairs were children of parents in the highest professional category; and the two brightest twins were sons of an Oxford don who had died just before they were born (their story is told in full by Conway, 1958, p. 186). Moreover, there was a disproportionately large number from the 'lower professional' category: parents of this class, when the family increased in size, often found it hard to preserve the standard of appearance they thought proper to their station and to give their children the type of education they deserved, since in those days education at a grammar school entailed payment of fees.

In arranging placements it is undoubtedly true that an endeavour is usually made to find foster-parents of the same social class as that of the original parents, but such efforts frequently fail. Parents in the skilled classes are not only reluctant to have their own twins separated, but also disinclined to accept foster children from other families. Parents in the unskilled classes can seldom provide suitable foster homes. On the other hand, childless couples who are well-to-do are often eager to adopt a child; and many of the children thus chosen are healthy and attractive-looking infants from the lower occupational categories. The consequence is that, contrary to Halsey's assumption, the average environmental difference between separated twins is actually greater than it would have been, had the homes been selected purely at random: only nine of the fifty-three separated twins were placed with foster-parents of the same social class as their own parents.

As regards range of intelligence, our group included a couple of mental defectives from special schools (I.Q. 66), and, at the other end of the scale, two scholarship winners (I.Q. 136 and 137)—a difference of 71 points, which is wider than the range one might normally expect in a sample of only fifty-three (namely, 4·5 S.D.). However, for correlations to be comparable, what are really important are not so much the *ranges* as the *standard deviations*. The standard deviation of the group of separated monozygotic twins was 15·3; and that of the ordinary siblings was 15·0. The American groups, it is true, showed a bigger range with standard deviations rising to 17·3; but the correlations now generally printed are nearly always corrected for this disparity (see Woodworth, 1941).

III. Results

Means and correlations

The average intelligence of the twins measured on a conventional I.Q. scale (S.D. = 15) was 97·8 for the separated monozygotes, 98·1 for monozygotes brought up together, 99·3 for the dizygotes as compared with 100·2 for the siblings and 100·0 for the population as a whole. The fact that twins—particularly uniovular—tend to have a lower average ability than ordinary children of the same social background has since been confirmed in several large-scale investigations carried out by Husén (1959), Sandon (1959), and others. The intra-class correlations obtained with the various groups for the different measurements and estimates are set out in Table 2. Since several writers (e.g. Heim, 1954; Hudson, 1965) have stated that the figures reported by Newman *et al.* (1937) for American children imply different conclusions from those drawn in my previous reports, I have appended the corresponding correlations obtained from their inquiry: their raw figures were corrected for age and range by McNemar, and the slight changes this involves have been accepted by Holzinger.

(*a*) *Intelligence*

(1) *Twins reared together.* It will be seen that, both in our own inquiries and in those of Newman, there are large and significant differences between the correlations for 'identical' and for 'non-identical' twins, when both members of the pairs have been brought up in their own homes. Between 'non-identical' twins (at any rate with our own data) the correlations are much the same as those between ordinary brothers and sisters; Newman reports slightly higher figures, as might be expected from the types of test employed. Shields obtained a coefficient of only 0·51 for his dizygotic twins, which is even lower than ours. There is a small positive correlation between the assessments for unrelated children brought up in the same home (0·27). This would seem attributable to the efforts (not very successful) to place these children in foster homes corresponding to those of their parents. Still more recent results, chiefly American, fully confirm our main finding. Using composite scores from tests for 'primary mental abilities' Blewett (1954) obtained correlations of 0·75 and 0·39 for monozygotic and dizygotic twins: but the size of his samples (26 pairs in each group) prevents the difference from being fully significant. Nichols (1965) used composite scores obtained from the National Merit Scholarship Qualifying Tests: pairs differing in school, sex or health records were excluded, and the correlations obtained were 0·87 for monozygotic twins (687 pairs) and 0·63 for dizygotic twins (482 pairs)

(2) *Twins reared apart.* Comparisons of the foregoing type are commonly dismissed on the ground that 'identical' twins naturally keep together much more closely than other siblings. I find it hard to believe that this of itself could account for the large differences observed. However, the study of cases in which twins of identical constitution have been separated almost from birth is likely to carry far more conviction. Unfortunately the number of investigations is extremely small.

In our own set of results the outstanding feature is undoubtedly the high correlation for 'intelligence' between monozygotic twins even when reared apart—0·87 as compared with 0·54 for dizygotic pairs reared together—a difference which is over four times its standard error. With children picked at random the average difference

Table 2. *Correlations for mental, educational, and physical characteristics*

	A. Burt *et al.*						B. Newman *et al.*		
	Mono-zygotic twins reared together	Mono-zygotic twins reared apart	Dizygotic twins reared together	Siblings reared together	Siblings reared apart	Unrelated children reared together	Mono-zygotic twins reared together	Mono-zygotic twins reared apart	Dizygotic twins reared together
Number of pairs*...	95	53	127	264	151	136	50	19	51
Intelligence									
Group test	0·944	0·771	0·552	0·545	0·412	0·281	0·922	0·727	0·621
Individual test	0·918	0·863	0·527	0·498	0·423	0·252	0·881	0·767	0·631
Final assessment	0·925	0·874	0·453	0·531	0·438	0·267	—	—	—
Educational									
Reading and spelling	0·951	0·597	0·919	0·842	0·490	0·545	—	—	—
Arithmetic	0·862	0·705	0·748	0·754	0·563	0·478	—	—	—
General attainments	0·983	0·623	0·831	0·803	0·526	0·537	0·892	0·583	0·696
Physical									
Height	0·962	0·943	0·472	0·501	0·536	−0·069	0·932	0·969	0·645
Weight	0·929	0·884	0·586	0·568	0·427	0·243	0·917	0·886	0·631
Head length	0·961	0·958	0·495	0·481	0·506	0·110	0·910	0·917	0·691
Head breath	0·977	0·960	0·541	0·510	0·492	0·082	0·908	0·880	0·654
Eye colour	1·000	1·000	0·516	0·554	0·524	0·104	—	—	—

* Figures for boys and girls have been calculated separately and then averaged. In columns 3, 4, 5 and 6 the correlations for head-length, head-breadth, and eye colour were based on samples of 100 only.

between their I.Q.s is approximately 17 points, with 'fraternal' twins 12 points, and with 'identical' twins, when reared apart, just under 6 points. The correlations reported by Newman (last 2 columns of Table 2) show similar but somewhat smaller differences. Shields (1962) in his recent publication reports a correlation of 0·77 for separated monozygotes age 8–59 yr (the figure is actually higher than that for monozygotes brought up together 0·76), and a correlation of 0·51 for dizygotes brought up together; but, owing to the small samples, the difference, taken by itself, is too small to be statistically significant. The reader will find it instructive to note how closely the various correlations for intelligence resemble those for most of the physical characteristics. Those for weight, however, are evidently affected by environmental conditions.

In most other researches on twins the investigators have not been in a position to secure the information needed to discriminate between monozygotic and dizygotic pairs. They have therefore merely recorded separate correlations for pairs of like and of unlike sex. Maxwell (1953, p. 144) has collected data from earlier studies; to these we can now add the figures recently reported by Vandenberg (1956), Sandon (1959) and Husén (1959). This yields seven independent researches, based on well over 1000 pairs of like sex and nearly 1000 of unlike. For intelligence the average correlations are 0·76 and 0·57 respectively. Applying the formula given above (p. 141) and using Fisher's z-transformation, the probable averages for the monozygotic and dizygotic pairs respectively work out at 0·89 and 0·56. In a survey just published, Wiseman (1964, p. 99) has computed estimates from data obtained in Manchester schools, using a rather different method; his figures are 0·92 for 'identical' twins and 0·51 for 'fraternal'. All four estimates, it will be observed, are in close agreement with our own, where the zygosity was determined by direct empirical evidence.

(*b*) *Attainments*

The differences obtained with the scholastic tests present a striking contrast with those for intelligence. In our own investigation the correlations for non-identical twins and for siblings reared together (0·83 and 0·80) are far higher than those for identical twins reared apart (0·62) and nearly as high as those for identical twins reared together. (The difference is even larger with Newman's groups.) For siblings reared apart the correlation sinks to 0·53. Here, therefore, the influence of environment is unmistakable. The coefficients which are most conspicuously increased are, as one might expect, those for verbal attainments.

Criticisms

The inferences which my colleagues and I drew from our earlier studies of twins (as well as from other lines of evidence) have been sharply criticized by those who favour an environmentalist theory. But the objections advanced rest almost entirely on armchair arguments: hardly any of the critics cite first-hand evidence of their own. Heim (1954), for example, observes that, even when so-called 'identical' twins have been brought up together, the correlations for intelligence 'still fall short of unity', and she contends that this tells against the genetic hypothesis. But no tests or assessments can claim perfect reliability; and the correlations she cites are almost, if not quite, as high as those obtained from the same individuals on two different

occasions. Quoting Newman, she tells us that 'when monozygotic twins are separated,...the differences between their scores are as great as those between unseparated dizygotic twins.' But here there is clearly a mistake. Newman's average difference for dizygotic twins is 9·2 points, but for the separated monozygotic twins only 8·2 points—a reduction which certainly cannot prove the superior importance of environment.

Maddox (1957), Halsey (1959), and Hudson (1965) are still more emphatic in their rejection of genetic influences. Like so many writers, however, they speak of 'differences in *intelligence*' and 'differences in *scores from intelligence tests*' as though the two were synonymous, and tacitly assume that what is true of one type of test—a verbal group test, for instance—holds good of all other assessments. In Newman's investigation the average difference between the separated twins is considerably increased by the big differences obtained in a very small number of pairs. There were four in which the difference amounted to at least 17 points; and in each there was marked difference in the amount of schooling received—ranging from 4 to 15 years. Gladys, for instance, brought up in an 'isolated part of the Rockies where there were no schools', obtained an I.Q. of only 92, whereas her twin sister Helen, who had been to college, obtained an I.Q. of 116—a difference of 24 points. Hudson quotes the case of Mary and Mabel where the difference was 17 points; here there was 4 years difference in schooling. But what does all this prove? Not that the innate intelligence of the twins was widely different, but merely that predominantly verbal tests, like the Otis and the Stanford–Binet, do not furnish very accurate assessments, when the schooling and cultural background are so dissimilar. Newman's own conclusion is very different from that drawn by our various critics. He observes that, even where there was a large discrepancy in the actual scores, it nevertheless seems probable that 'the twin with the lower I.Q. had an *inherited capacity* to reach the rating of the other, had he or she enjoyed the same opportunities'; on the other hand, 'even with a good education the poorly endowed person does not reach the level of a potentially able but poorly educated person' (Newman *et al.* 1937). And in a later summary of his main results he remarks that, 'throughout the whole study of identical twins reared apart', he was, as a geneticist, 'much more impressed with the very great intra-pair *similarities* of the twins, after they had been exposed to all sorts of environmental differences, than with the *differences*' (Gardner & Newman, 1940).

Environmental influences

I have never maintained, as McLeish (1963) implies, that environment has no effect whatever. I have always insisted that genetic and environmental factors are continually interacting from the very start. In our own data the environmental influences are most obvious in the case of group tests. And with every type of test or assessment a *small* portion of the correlation still seems to be attributable to environmental conditions. However, to demonstrate the importance of environmental opportunities it is quite misleading to pick out, as Dr Hudson and other critics have done, just one or two striking instances where a large discrepancy in the test-results is accompanied by a marked difference in home circumstances: once can always counter such an argument with cases, like that of 'George' and 'Llewellyn' (see Conway, 1958, p. 186), where, in spite of an exceptionally wide difference in up-

bringing, both twins happen to score almost exactly the same I.Q. The only satisfactory method is to correlate the *differences* between the various mental or scholastic assessments for each member of a pair with the *differences* in the material and cultural conditions (see Conway, 1959, pp. 8f.).

For this purpose we have assessed the economic and cultural conditions of the homes in terms of a conventional scale similar to that employed for assessing intelligence and educational attainments, namely, one in which the mean is 100 and the standard deviation is 15. The correlations thus obtained are shown in Table 3.

Table 3. *Correlations of differences for monozygotic twins reared apart*

	Home conditions	
Test results Differences in intelligence	Differences in cultural conditions	Differences in material conditions
Group test	0·43	0·21
Individual test	0·26	0·16
Final assessment	0·15	0·18
School attainments	0·74	0·37

Coefficients over 0·29 are significantly different from zero ($P < 0{\cdot}05$).

It will be seen that differences in educational attainments are highly correlated with differences in the cultural background: there is also a significant correlation between cultural differences and differences in the scores for the group test taken as they stand. But the correlations for the individual test and for the final assessment are so low as to be non-significant with a sample of this size. The differences in educational attainments show a small but significant correlation with differences in material conditions, chiefly no doubt because the latter are responsible for differences in the children's physical health and school attendance.

The multifactorial hypothesis

Most of the critics who seek to belittle the importance of mental inheritance seem content to examine just one particular investigation and base their arguments on the weaknesses they discern in that. They ignore the fact that the hereditarian's conclusions rest, not on a single research however elaborate, but on inferences drawn from a wide variety of different approaches—all leading to a systematic theory of mental inheritance, very similar to that arrived at by contemporary geneticists working in entirely different non-mental fields.

Accordingly, it seems desirable by way of conclusion to compare the correlations obtained from twins and siblings with those obtained from other pairs related by various degrees of affinity. The figures compiled from our London surveys are set out in Table 4. Since our last publication, further data have been collected for some of the smaller groups, and in these cases the correlations have been recalculated: the figures show little change, but their standard errors are smaller. We have endeavoured to select the individuals composing the groups so that they should, as far as possible, be genuinely representative of the population as a whole. With the smaller groups this has not been easy; but for all of them the standard deviations, which range from just under 14 to a little over 16 I.Q. points, are much the same. To compare or correlate figures for adults with those obtained from children may seem a questionable

procedure. But many of the pupils tested between 1914 and 1924 have since grown up; and it has often been possible to trace and re-test them as well as to test their own children. In that way correlations between assessments for these children and similar assessments secured from their parents when they were children can be computed. On the whole, they fully confirm the values obtained in the usual way.

Table 4. *Correlations between relatives*

	Burt		Other investigators		
	Number of pairs	Correlation	Number of investigations	Median correlation	Theoretical value
Direct line					
With parents (as adults)	374	0·49	13	0·50	0·49
With parents (as children)	106	0·56	—	—	0·49
With grandparents	132	0·33	2	0·24	0·31
Collaterals					
Between monozygotic twins					
Reared together	95	0·92	13	0·87	1·00
Reared apart	53	0·87	3	0·75	1·00
Between dizygotic twins					
Same sex	71	0·55	8	0·56	0·54
Different sex	56	0·52	6	0·49	0·50
Between siblings					
Reared together	264	0·53	36	0·55	0·52
Reared apart	151	0·44	33	0·47	0·52
Between uncle (or aunt) and nephew (or niece)	161	0·34	—	—	0·31
Between first cousins	215	0·28	2	0·26	0·18
Between second cousins	127	0·16	—	—	0·14
Unrelated persons					
Foster parent and child	88	0·19	3	0·20	0·00
Children reared together	136	0·27	4	0·23	0·00
Children reared apart	200	−0·04	2	−0·01	0·00

For purposes of comparison I also give medians for results reported by other investigators and the hypothetical values to be expected in accordance with what may be called the neo-Mendelian theory of mental inheritance. To calculate the latter the method used is a modification of that originally develop by Fisher (1918) in his study of body measurements. The formulae (Burt & Howard, 1956, pp. 115–16), unlike those used by most other writers, allow for two facts commonly ignored: in the case of intelligence there is (i) ample evidence for assortative mating between parents, and (ii) some evidence for a slight but incomplete amount of dominance. To some extent these two opposing influences tend to neutralize each other; but the net result is usually to raise the theoretical figures somewhat above those generally published, which tacitly assume that dominance is absent and that mating is perfectly random. In that case with simple multifactorial inheritance the theoretical correlations would be—with parents 0·5, with grandparents 0·25, with cousins 0·125, i.e. $(\frac{1}{2})^n$ for correlations between relatives of the nth degree. With intelligence we believe that unifactorial as well as multifactorial modes of transmission operate. And slight indications of sex-linkage, chiefly associated with the former, also seem discernible, particularly in the correlations for dizygotic twins. However, both these further influences, if they operate at all, are relatively small, and were consequently neglected in deducing the formulae used.

Erlenmeyer-Kimling & Jarvik (1964) have reported the results of a somewhat similar review of the literature. As they point out, 'while behaviour theory as yet makes few provisions for modern genetic concepts, the literature of the past half-century contains far more information than is generally realized about the relation between genotypic similarity and performance on mental tests'. They have located fifty-two such studies yielding 'over 30,000 correlational pairings from 8 countries in 4 continents', and present the main results in the form of an instructive diagram, which exhibits according to the degree of relation every correlation in their collection, together with the median for the various groups. Within some of the groups, particularly those where members of the same family have been brought up together, the coefficients exhibit a fairly wide range, e.g. for siblings they range from just over 0·30 to a little over 0·70. The reasons are fairly obvious. The low values have usually been obtained with somewhat unreliable tests, occasionally from but a single unvalidated test; often, too, the groups are fairly homogeneous. The high values are generally derived from heterogeneous samples, varying considerably in home background and education, and the tests are frequently verbal group tests, such as would be appreciably affected by differences in education. For most of the comparisons, however, there is a clear concentration of values near the mean or median. My own list includes a number of studies, chiefly British, which do not appear in the American collection; and with the writers' permission I have now added to my own earlier compilation data from several inquiries which they quote and which had escaped my notice.

In Table 4 I have given median values only; and I have indicated the number of investigations on which the medians are based. It will be seen that the values reported by other investigators tend to be somewhat higher than my own, presumably because many based their correlations on scores obtained from tests of a predominantly verbal type. If allowance is made for this, then, it will be seen that (except perhaps in the case of first cousins in my own research) both the figures obtained in the London inquiry and the medians of the figures published by other observers are in close agreement with the theoretical values we have calculated according to the neo-Mendelian hypothesis.

IV. Summary and conclusions

1. Various mental and physical characteristics have been measured for persons related in different degrees, and the correlations compared both with each other and with those obtained by other investigators, as well as with the values to be expected in accordance with the modified theory of multifactorial inheritance outlined in an earlier paper (Burt & Howard, 1956). In particular, an intensive correlational study has been made of monozygotic twins reared together and apart.

2. For assessments of 'intelligence' the correlations from unrelated pairs of children brought up together are positive but comparatively small; those from related pairs increase progressively according to the closeness of family relation. The correlation for monozygotic twins reared in separate environments amounts to as much as 0·88, and is but slightly increased where such twins have been reared together. On the other hand, the correlations for school attainments vary closely with similarity in environmental circumstances. From this it may be inferred that individual

differences in 'intelligence', particularly when the assessments have been carefully checked, are influenced far more by genetic constitution, or what is popularly termed 'heredity', than by post-natal or environmental conditions.

3. The detailed values for the different groups obtained both in my own investigations and in those of other writers, agree satisfactorily with the view that the genetic tendencies which are responsible for individual differences in intelligence are in the main (though probably not exclusively) transmitted in accordance with a multifactorial or polygenic hypothesis, due allowance being made for assortative mating and partial dominance.

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