AN INVESTIGATION OF THE LINKAGE RELATIONSHIPS OF THE BLOOD GROUPS AND TYPES WITH HAND PATTERNS AND HANDEDNESS

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The blood groups and the M and N agglutinogen reactions are unique among known human traits, in that their modes of inheritance are simple and clear, they remain constant throughout the life of the individual, and all the genes involved are comparatively common in most populations. Such traits are ideal for linkage studies and they have probably been used for this purpose more frequently than any other human traits. (Finney, 3,4,5), (Penrose, 6,7), (Snyder, 10,11), (Weiner, 12).

Dermatoglyphics are similar to the blood reactions in that they remain constant throughout the life of the individual, that they have a genetic basis, and that the majority of the genes involved appear to be comparatively common in most populations. They differ from the blood reactions in that the number of genes involved and their reactions are not known, and that their expression is modified to a certain extent by circumstances in utero. All known dermatoglyphic features show some degree of intra-pair variation in identical twins, although these differences are much less frequent than those encountered within fraternal twins and sibs. (Rife, 8).

Functional handedness is, of course, a much more subjective trait than either the blood reactions or dermatoglyphics. Presumptive evidence of autosomal linkage between handedness and palm pattern D in the fourth interdigital area has been found, (Rife, 8), and would seem to definitely indicate a genetic basis for handedness although the mode of its inheritance is not fully understood.

The investigation reported here is concerned with tests for linkage of each of the blood reactions with handedness and hand patterns. The data were obtained from sibships within ten families of various sizes. Only unimanual handedness was considered, and classification was determined from the individual's testimony and by the performance of several operations, including throwing, sewing and driving a nail. Individuals performing one or more of these acts with the left hand were classed as left-handed, only those performing all one-handed operations with the right hand being classed as right-handers.

Five dermatoglyphic features are included in the tests. Figures 1, 2, and 3 show the appearance of each of the areas concerned. Palm patterns may be whorls, loops or vestigials. An area is considered patternless when all of the ridges run through to the margin of the palm (see Figs. 1 and 2). If Line C recurves to the margin of the palm between the triradii at the bases of the ring and little fingers, a loop is formed on the fourth interdigital area, if it recurves in the other direction, emerging between the triradii of the middle and ring fingers, a loop is formed on the third interdigital area. Main Line C is sometimes absent or abortive in one or both hands of an individual which accounts for the lower number of pairs recorded for Line C in Tables I and II. Whorls on finger-tips always have two triradii, loops one and arches none. As arches are comparatively infrequent, individuals are classed as to the number of whorls present, which varies from zero to ten.

Individuals are classed in three groups in respect to Line C, those forming patterns on the fourth-interdigitals of both hands, the third interdigitals of both hands, and the fourth interdigital on one hand and the third interdigital of the other. For the hypothenar, thenar and fourth interdigital Pattern D, individuals

are classed as to presence or absence. Those having patterns on either or both are placed in the same category, as presence.

Within recent years several methods have been devised for detecting linkage in man, notably those of Weiner (12), Burks (1), Penrose (6, 7), Haldane (2), and Finney (3, 4, 5). The methods of Haldane and Finney can be applied only where we know the specific modes of inheritance of the traits concerned, and obviously are of no value in testing dermatoglyphics and handedness.

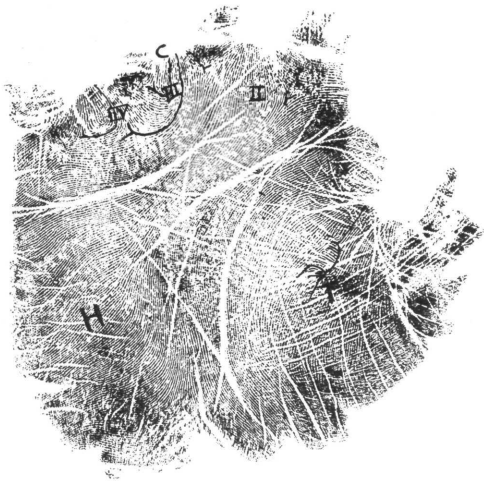

FIG. 1. Print of left palm. H indicates hypothenar area, T—thenar area, II—second interdigital area, III—third interdigital area, IV—fourth interdigital area, C—main line C. This palm shows a vestigial thenar pattern, a loop in the third interdigital area formed by main line C, and an accessory triradius in the fourth interdigital area, resulting in a D pattern. No patterns are present in the hypothenear and second interdigital areas.

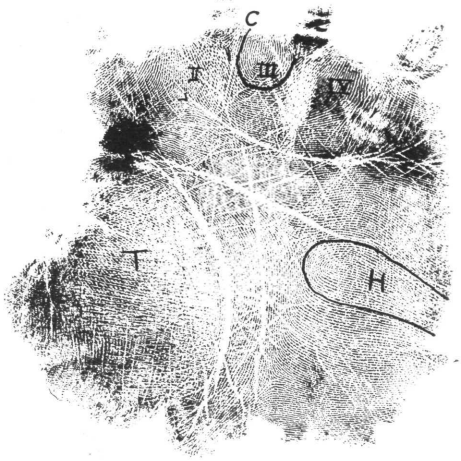

FIG. 2. Print of a right palm. No patterns are present on the thenar, second and fourth interdigital areas. Main line C forms a loop in the third interdigital area, and an ulnar loop is present on the hypothenar area.

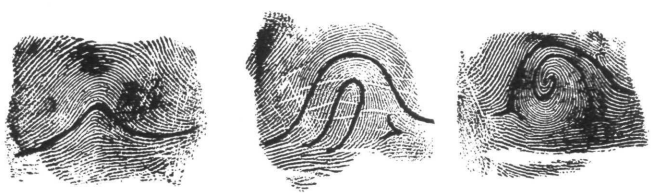

FIGURE 3. Types of finger patterns. a—arch, b—loop, c—whorl. Arches are characterized by the absence of triradii, loops have one, and whorls three. Both whorls and loops occur on palm pattern areas, loops being the most abundant pattern type in both fingers and palms.

Our tests are based upon the paired sib technique of Burks and Penrose, in which pairs are grouped into four classes: those alike in both traits, those alike in the first and unlike in the second, those alike in the second and unlike in the

first, and those unlike in both traits. These are arranged in a 2 x 2 table, those alike in both and unlike in both forming one diagonal, and the two groups alike on one and unlike in the other trait forming the other diagonal. A modification was necessary in testing for linkage between whorls and the blood reaction, as whorls are quantitative. Pairs alike in blood reaction (Column 1, Table I) are classed as to number of intra-pair difference in whorls, (Column 2), as are pairs unlike in blood reaction (Columns 3 and 4). If pairs unlike in blood reaction show significantly greater intra-pair differences in whorls than do pairs alike in blood, it may be considered presumptive evidence of linkage.

Inspection of Tables I and II reveal only one significant Chi-square value, that of whorl frequency and the blood groups. However, pattern D and the M and N types show a Chi-square value of 3.44, only slightly below a significant level.

We have consequently tested whorls versus blood groups, and pattern D versus the M and N types by means of Penrose's technique for graded characters.

TABLE I

	Alike in both traits	Alike in blood, different in other traits	Unlike in blood, alike in other traits	Unlike in both traits	Total pairs	X^2
	1	2	3	4		
Hypothenar....	95	81	45	29	250	0.59
Thenar.....	132	42	63	13	250	1.50
Line C.....	37	54	16	22	129	0.02
Pattern D.....	121	53	45	31	250	2.50
Whorls.....	167	318	76	207	768	4.75
Handedness....	107	47	67	29	250	0.01

The above table shows the numbers of each of the various combinations of sib pairs used in testing for linkage between the blood groups and the various hand patterns and handedness. Chi-square values obtained are shown in the last column. Any X^2 value below 3.841 is not considered significant. Whorls differ from the other traits in the above classification, in that Column 1 gives the total number of pairs alike in blood group, Column 2 the total intrapair differences of those alike in blood, Column 3 the total number of pairs unlike in blood group, and Column 4 the total intrapair differences of those unlike in blood.

TABLE II

	Alike in both traits	Alike in blood, unlike in other trait	Unlike in blood, alike in other trait	Unlike in both traits	Total pairs	X^2
	1	2	3	4		
Hypothenar....	97	77	47	31	252	0.44
Thenar.....	133	41	66	12	252	2.17
Line C.....	40	59	20	22	141	0.63
Pattern D.....	119	56	43	34	252	3.44
Whorls.....	165	439	80	204	888	0.07
Handedness....	108	45	67	32	252	0.24

Data used for testing linkage between M and N blood types and hand patterns and handedness. Whorls are classed as in Table II.

While there is no evidence of linkage for Line C and the blood reactions on the basis of the tests shown in Tables I and II, the fact that there are three classes of individuals in regard to Line C may raise some question as to the validity of that particular test. Thus, it was thought advisable to obtain a further check by the method for graded characters.

Table III shows no significant association for any of the traits compared. It seems justifiable on the basis of this study to conclude, therefore, that genes determining the blood reactions are probably located on different chromosomes from those determining handedness and hand patterns.

TABLE III

	ϕ	σ	$\frac{\phi}{\sigma}$
Whorls vs. Antigen A	.01	.24	0.08
Whorls vs. Antigen B	.04	.24	0.17
Pattern D vs. Antigen MN	.44	.246	1.79
Line C vs. Antigen A	.09	.27	0.30
Line C vs. Antigen B	.71	.47	1.69
Line C vs. Antigens MN	.08	.26	0.30

Values obtained in testing for linkage between the above traits by the Penrose method for graded characters. If $\frac{\phi}{\sigma}$ is less than two, the evidence for linkage is negative.

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