Dept. of Medical Genetics
Cleveland Psychiatric Inst. - Cleveland, Ohio

Heredity and Dermal Patterns in the Interdigital Areas of the Palm *

Edward V. Glanville

Evidence of a genetic control of dermal ridge patterns was put forward as early as 1892 by Sir Francis Galton. Subsequent research has confirmed the importance of heredity but has also shown that data for the majority of dermal characteristics do not agree with a simple dominant or recessive Mendelian mode of inheritance. Instead, most features appear to be governed by a polygenic system and quantitative methods of analysis are required for their study. One method which can be employed to overcome the difficulty of converting the morphological features of the dermal patterns into metrical traits is to use ridge-counts, that is, to count the numbers of dermal ridges intervening between cardinal points on the hand (Bonnevie, 1924; Holt, 1952; Pons, 1964). Another is to measure the angle subtended at one position by two other points, for example the *atd* angle described by Penrose (1954).

In the present paper, an attempt has been made to analyse some of the hereditary factors associated with the dermal patterns in the interdigital areas of the hand. Twin and pedigree data have been used to investigate the position and type of pattern and a quantitative analysis of the size of the patterns has been made by calculation of the correlation coefficients for pattern ridge-counts between family relatives.

The diagrammatic representation of a hand in Fig. 1 shows the interdigital areas numbered I to IV. The thenar-first interdigital area has not been included in the analysis as the patterns in this area are different from those in areas II, III and IV and are not suitable for quantitative analysis. There is usually a triradius at the base of each finger, with the exception of the thumb, and these are lettered *a* to *d* in Fig. 1 (A triradius is a Y-shaped confluence at which dermal ridges converge from three directions). One of these four triradii is occasionally missing, almost invariably *c*, and sometimes one or more accessory triradii are present. Patterns in the inter-

* Supported by the U. S. Public Health Service, N. I. H., research grant nos. MH 07820-01 and HD 00581-02 (Arnold R. Kaplan and Roland Fischer, principal investigators) and grant nos. GRS 05251 and GRS 05563 (General Research Support grant from the U. S. Public Health Service to the Cleveland Psychiatric Institute).

Ricevuto il 10. XII. 64

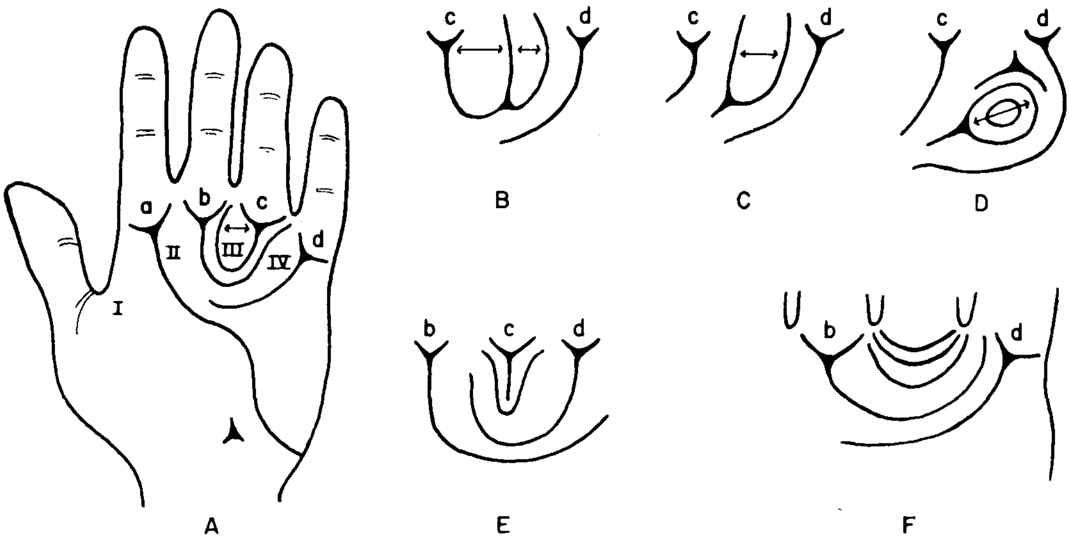

Fig. 1. Patterns in the interdigital areas of the palm. *A*, single loop; *B*, twin loops with an accessory triradius; *C*, single loop with accessory triradius; *D*, whorl; *E*, tented arch; *F*, plain arch

digital areas can be distinguished by tracing the dermal ridges which emerge from the triradii. True patterns may occur in one, two or all of the interdigital areas of the same hand. Areas without true patterns are occupied by " open-fields " of more or less parallel ridges. The most common pattern is the loop, which may be single or paired within a given area but plain and tented arches occur and more rarely whorls.

Particular interest in the interdigital areas of the palm stems from the fact that the patterns appear to be modified in certain syndromes associated with chromosonal defects, such as mongolism and Turner's syndrome (Fang, 1950; Penrose, 1963). Racial variation in patterns in these areas is well known (Cummins and Midlo, 1943). Variation between pairs of identical twins is often considerable in this region of the hand (Meyer-Heydenhagen, 1934) and patterns in the interdigital areas appear to be more susceptible to non-genetic modification early in embryonic development than other dermal features such as the *atd* angle or the finger ridge-count.

Material and methods

The sample consisted of 566 individuals, 267 male and 299 female. It included 118 husband-wife pairs with their children and also a number of incomplete families for which data on one or other of the parents was not available. Thirty-two pairs of monozygotic twins and 40 pairs of dizygotic twins were included. Zygosity of the twins was determined by examination of non-dermal morphological features and by comparison of 8 to 10 blood and serum factors. Contact with the majority of subjects was established through the Cleveland Area Twin Registry. The remainder of the sample consisted of the families and friends of individuals on the staff of the Cleveland Psychiatric Institute. All were of European descent and were apparently free of congenital defect.

The method of determining the ridge-count of patterns in the interdigital areas was as follows:

a) The dermal ridges originating from the triradii, that is, the main lines, were traced on a print of the hand.

b) Loops: the count was made across a loop at its greatest width at right angles to the long axis, the termini being the main line bounding the pattern. The level at which the count was made is indicated by a double-headed arrow in Fig. 1. A single loop is shown in Fig. 1*A* and a single loop with an accessory triradius in Fig. 1*C*. When more than one loop occurred on the same palm either in the same interdigital area (Fig. 1*B*) or in different areas, the average count was recorded.

c) Whorls: patterns of this type are accompanied by accessory triradii and are usually of small size (Fig. 1*D*). The count was made across the largest entire ring at its greatest width. When more than one pattern was present on the same palm the average count was recorded.

d) Arches: a tented arch is characterized by a main line (which almost invariably originates in the *c* triradius) which stops short without any apparent tendency to curve in either direction (Fig. 1*E*). If the triradius is absent the pattern is classified as a plain arch (Fig. 1*F*). The ridge count for arches of both types was recorded as zero.

e) Some degree of arbitrariness was involved in tracing the main lines in a few instances in which the lines branched or breaks in the dermal ridges occured. In the former case the branch which would give the smaller count was followed. If a break occured in the main dermal ridge and a loop was clearly evident, the line was continued across the break so as to continue the curve as smoothly as possible.

The total ridge-count was used in analysing the data, that is, the combined total for left and right hands. The degree of resemblance between family relatives was measured by means of the correlation coefficient. The method was invented by Galton and has been widely used in the study of quantitative traits. A summary of its uses has been provided by Fraser Roberts (1964).

Results

The type and position of patterns on the right and left hands of male and female subjects are shown in Tab. 1. There was no marked difference between the sexes in this sample but a distinct bilateral asymmetry was evident, particularly in the relative number of single loops observed in areas III and IV.

The ridge-count for patterns in areas II, III and IV are shown in Tab. 2. Arches were not included in this data as they involve both areas III and IV. It is evident

Tab. 1. Percentage of palms showing patterns in interdigital areas II, III and IV. A single loop in area III is shown as III; two loops within area IV as IV, IV; two loops, one within III and one within IV as III, IV; etc.

	Loop or loops in interdigital areas									Arches		Whorls, other patterns	Total no.
	III	IV	II III	II IV	III IV	IV IV	II III IV	II IV IV	III IV IV	Plain	Tented		
Left hand													
♂	21.0	46.8	1.1	0.4	4.9	7.5	0.7	0.4	0.4	6.7	8.2	1.9	267
♀	26.1	45.5	0.0	0.0	6.7	4.4	0.3	0.3	0.3	6.7	7.7	2.0	299
Right hand													
♂	42.0	33.3	1.1	0.0	7.5	2.2	1.1	0.4	0.0	4.9	5.6	1.9	267
♀	40.8	35.1	0.7	0.3	6.7	1.3	0.7	0.0	0.7	6.4	5.0	2.3	299

Tab. 2. Ridge-count of patterns in interdigital areas II, III and IV on left and right hands of male and female subjects; mean counts and their standard deviations are shown

Interdigital area		Left hand		Right hand	
		Mean	S. D.	Mean	S. D.
II	♂	8.67	4.33	12.00	5.00
	♀	7.00	5.00	12.50	5.77
III	♂	10.87	5.23	15.82	6.19
	♀	11.20	5.24	15.95	6.67
IV	♂	15.62	8.58	19.88	9.82
	♀	16.47	9.41	20.07	10.86

that the count tended to be higher on the right hand than on the left. On the average, the count in area IV tended to be larger by approximately 5 than that in area III. To compensate for this difference, a correction factor of 5 was added to the count of all patterns in area III. For a similar reason a correction factor of 8 was added to the count of all patterns in area II. The total ridge-counts for the entire sample after the correction factors had been introduced are shown in Fig. 2. As the dermal ridge patterns are determined before birth, no adjustment for age was necessary.

The correlation coefficients between family relatives were calculated using the total interdigital pattern ridge-count. The results are given in Tab. 3. In this table, the number of paired comparisons and the standard error are given with each correlation coefficient.

https://doi.org/10.1017/S1120962300013676 Published online by Cambridge University Press

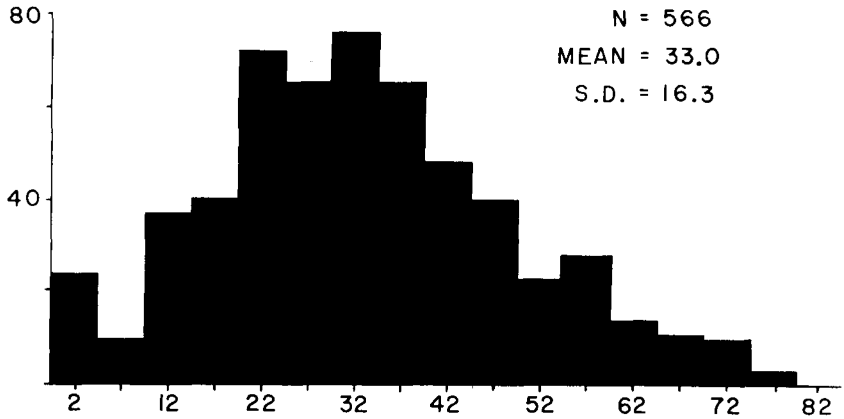

Fig. 2. Total interdigital ridge-count

The influence of heredity in the determination of the type and position of patterns has been studied by estimating concordance rates between twins and other family members and by pedigree studies. The concordance rates for monozygotic and dizygotic twins, sib pairs and husband-wife pairs, are shown in Tab. 4. Pairs were classified as concordant for position and type of pattern if both fell within the same classification group of the 12 possible types shown in Tab. 1.

Pedigree studies permitted a comparison to be made between patterns occuring in parents and in their children. The more common parental combinations with their progeny are listed in Tab. 5. No significant difference was observed in reciprocal crosses and data from these were therefore combined in the table. The data for left and right hands have been considered independently. The same method of repre-

Tab. 3. Correlation coefficients between relatives for the total interdigital pattern ridge-count

Relationship	No. of pairs	Correlation coefficient
Father-mother	118	.102 ± .09
Father-son	136	.425 ± .07
Father-daughter	150	.360 ± .07
Mother-son	140	.346 ± .07
Mother-daughter	160	.378 ± .07
Son-son	85	.328 ± .10
Daughter-daughter	117	.412 ± .08
Son-daughter	140	.358 ± .07
Twins (MZ)	32	.881 ± .04
Twins (DZ)	40	.455 ± .13
Midparent-child	283	.531 ± .04

Tab. 4. Percentage concordance and discordance for the relative position and type of pattern in interdigital areas II, III and IV of the palm

Relationship	No. of pairs	Left hand		Right hand	
		Concordant	Discordant	Concordant	Discordant
Twins (MZ)	32	87.5	12.5	71.9	28.1
Twins (DZ)	40	40.0	60.0	40.0	60.0
Sib-sib	342	41.5	58.5	43.0	57.0
Father-mother	118	30.5	69.5	28.8	71.2

Tab. 5. Pedigree data for position and type of pattern in the interdigital areas of the palm. Only the more common parental combinations are shown, but all progeny of these crosses are listed. Symbols are the same as in Tab. 1

Cross (parental types)	Progeny							
	Loop in interdigital areas						Arch	Whorls or other patterns
	III	IV	II, III	II, IV	III, IV	IV, IV		
Left hand								
III × III	19	11		1	5	2	2	
III × IV	24	38	1		1	3	3	2
IV × IV	5	40			2	4	8	
III × III, IV	2	5				1		
III × IV, IV		3	1				2	
IV × III, IV	2	14					1	
IV × IV, IV		8			2	1	4	
Right hand								
III × III	35	9	1		2		5	1
III × IV	42	43			5		7	2
IV × IV	6	24			1	2	2	
III × III, IV	11	5			1	1	2	1
III × IV, IV		1			3			1
IV × III, IV	6	13			1	1	2	
IV × IV, IV			1					

senting the position and type of pattern has been used as previously, for example, a single loop in area III is shown as III and two loops, one in area III and one in area IV of the same hand as III, IV etc. Considering first the left hand, the cross III × III yielded 48% of III and 28% of IV (with 24% other types). By contrast, the cross IV × IV yielded 9% of III and 68% of IV, and the cross III × IV, 33% of III and 53% of IV. On the right hand, the yields were: III × III, 66% of III and 17% of IV; IV × IV, 17% of III and 68% of IV; III × IV, 42% of III and 43% of IV.

https://doi.org/10.1017/S1120962300013676 Published online by Cambridge University Press

Discussion

The major features of the patterns formed by the dermal ridges are determined early in embryonic development. Dermatoglyphic patterns are therefore among the relatively few human characteristics which are not modified by environmental influences after birth. They provide traits which are well suited for genetic and anthropological investigation, particularly when they can be analysed in a quantitative manner.

The correlation coefficient provides not only a measure of the degree of similarity between relatives, but also, due to the mathematical theories of Fisher (1918) and Penrose (1949), information about the mode of inheritance.

Examination of the data in Tab. 3 reveals no evidence of the effects of either sex-linkage or sex-limitation. The parent-child coefficients were found to range between .346 and .425 and the sib-sib correlations between .328 and .412. The similarity in the values of the parent-child and sib-sib correlations indicates that dominance is not important. Dominance would be expected to decrease the parent-child correlation relative to the sib-sib. If the total variation was due to hereditary factors, additive genes without dominance would be expected to give values of .5 for both parent-child and sib-sib correlation coefficients. The fact that the observed values are less than .5 may be attributed to non-hereditary factors. Further evidence that an appreciable amount of the variation observed is caused by non-genetic factors is that the correlation coefficient for monozygotic twins was only .881 $\pm$.04.

Comparison between the midparent ridge-count, that is, the mean of the parental counts, and the counts of the children provides further information about the mode of inheritance. With additive genes the theoretical regression of child on midparent is 1, because all of the child's genes come from the parents. But the regression of midparent on child is only .5 because only one-half of the parental genes are identical with those in the child, the others being on the average those of the general population. The regressions are therefore asymmetrical and the correlation coefficient is $\sqrt{1 \times .5} = .71$. The observed correlation coefficient was .531 $\pm$.04 (Tab. 3), and the regression of child on midparent .771 $\pm$.07 and the regression of midparent on child .366 $\pm$.03. Dominance would be expected to decrease the regression of child on midparent, but in this instance the difference between the theoretical value of 1.0 and the observed .771 can probably be attributed to non-genetic factors. Penrose (1949) has pointed out that not only would dominance tend to lower the regression of child on midparent but that the regression would become nonlinear. There is no evidence of this in the observed data.

The data for the interdigital pattern ridge-count given in Tab. 2 shows a clear trend towards bilateral asymmetry in the size of the pattern. The ridge-count on the right hand was on the average 4 or 5 larger than on the left. Bilateral asymmetry is not uncommon among dermal characteristics and racial variation in this feature has been described (Cummins and Midlo, 1943). Bilateral asymmetry is also evident in the relative position of patterns in the interdigital areas (Tab. 1). The same apparent trend in favor of pattern formation in area III on the right hand but in area IV on the left is shown by the pedigree data in Tab. 5 when the progeny from the same parental combinations are compared for right and left hands. The underlying cause of this tendency is not clear.

A comparative study of American Negro males and males of European descent made by Glanville and Poelking (in press) demonstrated that loops in the interdigital areas of the palm of Negroes tended to be smaller in both the third and fourth interdigital areas on both hands. The relative proportion of patterns in areas III and IV also differed markedly in the two groups. The present investigation has shown that these ethnic differences probably have a genetic basis.

Summary

Hereditary factors involved in the determination of the size, relative position and type of pattern formed by the dermal ridges in the interdigital areas of the palm have been investigated by means of twin and family studies. The sample consisted of 566 individuals of European descent. The ridge-counts of patterns in the interdigital areas were determined. Correction factors were introduced to compensate for different average counts in each interdigital area. The correlation coefficients between family relatives were calculated using the ridge-counts. The coefficient for monozygotic twins was $.88 \pm .04$ and for parent and child from .346 to .425 and for sib pairs from .328 to .412. There was no evidence of sex-linkage or of the effects of dominance. Variation appeared to be determined by additive genes but an appreciable amount of variation of non-genetic origin was observed. Bilateral asymmetry in the ridge-count, type of pattern and relative position of the patterns was evident. Concordance rates in twins and other family members and pedigree data provided further evidence of hereditary influence in the determination of the position and type of pattern in the interdigital areas.

References

Bonnevie K.: Studies on papillary patterns of human fingers. J. Genet., *15*: 1-112, 1924.

Cummins H. & Midlo C.: Finger prints, palms and soles. The Blakiston Company, Philadelphia, 1943.

Fang T. C.: The third interdigital patterns on the palms of the general British population, mongoloid and non-mongoloid mental defectives. J. Ment. Sci., *96*: 780-787, 1950.

Fisher R. A.: The correlation between relatives on the supposition of mendelian inheritance. Trans. Roy. Soc. Edin., *52*: 399-433, 1918.

Glanville E. V. & Poelking J.: Palmar dermatoglyphics in White, Negro and mixed groups. Am. J. Phys. Anthrop. (in press).

Holt S. B.: Genetics of dermal ridges: inheritance of total finger ridge-count. Ann. Eugen., Lond. *17*: 140-161, 1952.

Meyer-Heydenhagen G.: Die palmaren Hautleisten bei Zwillingen. Ztsch. f. Morphol. u. Anthropol., *33*: 1-42. 1934.
Penrose L. S.: Finger-prints, palms and chromosomes. Nature *197*: 933-938, 1963.
— The distal triradius *t* on the hands of parents and sibs of mongol imbeciles. Ann. Hum. Genet., *19*: 10-38, 1954.
— The biology of mental defect. Sidgwick and Jackson, London. 1949.
Pons J.: Genetics of the *a-b* ridge-count on the human palm. Ann. Human Genet. *27*: 273-277, 1964.
Roberts J. A. F.: Multifactorial inheritance and human disease. *In* Progress in Medical Genetics, Vol. 3 (A. G. Steinberg and A. G. Bearn, eds.) Grune and Stratton, New York, 1964.

RIASSUNTO

Sono stati studiati, mediante indagini gemellari e familiari, i fattori ereditari interessati nella determinazione della grandezza, della posizione relativa e del tipo di disegno delle creste delle regioni interdigitali del palmo. Il campione era composto da 566 individui di origine europea. È stato effettuato il conto delle creste nelle regioni interdigitali. Sono stati introdotti fattori di correzione per compensare i diversi conteggi medi in ogni regione interdigitale. Mediante il conteggio delle creste sono stati calcolati i coefficienti di correlazione fra i membri delle famiglie. Il coefficiente fra gemelli MZ è risultato essere di 0,88 $\pm$ 0,04, quello fra genitore e figlio di 0,346—0,425, e quello fra coppie di siblings di 0,328—0,412. Non vi sono prove di concatenazione al sesso o di effetti di dominanza. La variabilità è risultata essere determinata da geni additivi, ma è stata anche osservata una notevole variabilità non genetica. É risultata evidente una asimmetria bilaterale nel conto delle creste, nel tipo di disegno e nella posizione relativa. I livelli di concordanza nei gemelli e negli altri componenti delle famiglie, insieme ai dati genealogici, costituiscono un'ulteriore dimostrazione dell'influenza dell'eredità nella determinazione della posizione e del tipo di figura nelle regioni interdigitali.

RÉSUMÉ

Moyennant l'étude de jumeaux et familles, l'A. a analysé les facteurs héréditaires qui interviennent dans la détermination de la grandeur, de la position relative et du type de dessin des crêtes des régions interdigitales de la paume. L'échantillon consistait en 566 individus d'origine européenne. La compte des crêtes dans les régions interdigitales fut effectué. Des facteurs de correction furent introduits afin de compenser les divers comptes moyens pour chaque région interdigitale. Les coefficients de corrélation entre les différents membres des familles furent calculés moyennant les comptes des crêtes. Le coefficient entre jumeaux MZ résulta être de 0,88 $\pm$ 0,04, celui entre parent et fils de 0,346—0,425 et celui entre siblings de 0,328—0,412. Il n'y a pas de preuves de sex-linkage ou d'effets de dominance. La variabilité résulta être determinée par des gènes additifs, mais on a aussi bien observé une remarcable variabilité non-génétique. Une asymétrie bilatérale dans le compte des crêtes, le type de dessin et la position relative résulta évidente. Les niveaux de concordance chez les jumeaux et les autres membres des familles, ainsi que les données généalogiques, constituent une preuve de plus de l'importance de l'hérédité dans la détermination de la position et du type de dessin dans les régions interdigitales.

ZUSAMMENFASSUNG

Im Zwillings- und Sippenversuch wurden die Erbfaktoren untersucht, welche die Größe, die gegenseitige Position und die Zeichnungsart der Hautleisten zwischen den Fingern bestimmen. Die Musterauslese bestand aus 566 Personen europäischen Ursprungs. Es wurden die Hautleisten zwischen den Fingern gezählt und Korrekturfaktoren eingeführt, um die verschiedenen Durchschnittserrechnungen zwischen den einzelnen Fingern auszugleichen. Durch Auszählung der Hautleisten wurden die Korrelations-Koeffizienten zwischen den Familienmitgliedern errechnet. Es zeigte sich, daß der Korrelations-Koeffizient zwischen EZ-Paaren 0,88 ± 0,04, zwischen einem Elternteil und Kind 0,346—0,425 und zwischen einem Geschwisterpaar 0,328—0,412 beträgt. Geschlechtsgebundenheit oder Dominanzwirkungen konnten nicht bewiesen werden. Die Variabilität wird durch additive Gene bedingt, doch war auch eine erhebliche nicht erbliche Variabilität festzustellen. Eine bilaterale Asymmetrie in der Zahl der Hautleisten, im Typ der Hautleistenzeichnung und in der gegenseitigen Position derselben wurde deutlich. Die hohen Konkordanzziffern bei Zwillingen und anderen Familienmitgliedern ergeben zusammen mit den Stammbaumerhebungen einen weiteren Beweis dafür, daß bei Festsetzung der Position und des Zeichnungstypes der Hautleisten zwischen den Fingern die Vererbung eine wesentliche Rolle spielt.