PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

The Patterns in Thumb and Finger Marks. On Their Arrangement into Naturally Distinct Classes, the Permanence of the Papillary Ridges that Make Them, and the Resemblance of Their Classes to Ordinary Genera

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Phil. Trans. R. Soc. Lond. B 1891 **182**, 1-23
doi: 10.1098/rstb.1891.0001

PHILOSOPHICAL TRANSACTIONS.

I. *The Patterns in Thumb and Finger Marks.—On their arrangement into naturally distinct classes, the permanence of the papillary ridges that make them, and the resemblance of their classes to ordinary genera.*

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Received November 3,—Read November 27, 1890.

[PLATES 1, 2.]

I PROPOSE to describe some results of a recent inquiry into the patterns formed by the papillary ridges upon the bulbs of the thumbs and fingers of different persons. The points upon which I shall chiefly dwell are, the classification of the patterns, their permanence throughout life, and the apt confirmation they afford of certain views concerning the more important conditions by which the genera of plants and animals are determined.

My attention was drawn to the subject nearly three years ago, when preparing a lecture for the Royal Institution on "Personal Identification." (See either the 'Journal of the Royal Institution,' for Friday, May 25th, 1888, or 'Nature,' June 28th, 1888, in which the portion of the lecture with which we are now concerned is printed.)

I would refer to that lecture, as it contains numerous references to the existing literature on the subject, and because it formed the starting point from which the present inquiry proceeded. Two conclusions were strongly impressed on my mind at the time when I gave it :—

(1.) That although much had been asserted as to the permanence of these markings, and though I was then able, through the kindness of Sir W. J. HERSCHEL, to submit two instances in proof, the truth of the assertion had never been adequately investigated.

(2.) That the method of classifying the markings, which was originated by PURKINJE, in his 'Commentatio,' dated 1823 (a copy of this rare pamphlet is now in the library of the College of Surgeons), and subsequently adopted by other writers, with more or less variation, was not based on a sufficiently good foundation.

Since then I have steadily pursued the inquiry and found its interests to widen considerably as I proceeded. They led in many directions, and among others to the topic that will be the last discussed.

Data.

The data on which this memoir is based are :—

(1.) The impressions of the two thumbs of about 2500 persons made for me, at my Anthropometric Laboratory, together with several impressions of the fingers.

(2.) A small and unique collection of impressions put at my disposal by Sir W. J. HERSCHEL, of which one half were taken many years ago, and the other half were taken quite recently from the same persons. I will speak of these more at length when the time comes for using them.

As regards the first set :—

I chose the two thumbs rather than two adjacent fingers on the same hand, in order to obtain data respecting symmetry, on which however very little will be said here, and I chose a thumb of each hand, rather than a finger of each hand, because the thumb being greater than that of the finger the width of it affords a proportionately larger field for variety of pattern. However, all that will be said about thumb marks, applies with but little reservation to finger marks, but with much more reservation to those of the toe.

I have myself not studied the latter, but PURKINJE states that the patterns of the toes are always of that particular sort which I shall define later on, and call a loop.

Origin of the Ridges.

I do not attempt to discuss the origin of the papillary ridges, because my knowledge is entirely second hand, and it would be presumptuous in me to do so. It will be sufficient to say that KOLLMANN's (A. KOLLMANN, 'Der Tastapparat der Hand.' Hamburg and Leipzig, LEOPOLD VOSS, 1883) dissections seem to prove (see his figs. 19, 20) :—

(1.) That each of the papillæ (which lie below the cuticle) has two heads, which I will symbolise by the fork in the printed capital letter Y.

(2.) That the duct of the sudorific glands in passing outwards between the papillæ, is bound up, as in a bundle, with the adjacent head of each of two neighbouring papillæ. So that if the sudorific duct is symbolised by the printed letter I, a section across the ridges might be symbolised by a row of the letters Y and I printed alternately, thus—YIYIYIY. Then the union of the I with the adjacent prongs of two Y's forms the foundation of a ridge, and the clefts between the heads of the Y's correspond to the furrows.

There is, I believe, no adequate explanation of the fact that the prominences through which the ducts issue, on the bulbs of the finger, and in some other parts, are strongly disposed to arrange themselves into continuous ridges, and not to form isolated craters. There is, however, abundant analogy in the animal kingdom of external ridges of various sorts running in a variety of spirals and whorls.

Obtaining Impressions.

The impressions in my collection were made by thinly inking a copper plate with printer's ink, by means of a printer's roller. The plate was about eight inches by twelve, and fixed to a solid block of wood. The thumb was rather lightly rolled on the inked plate, not simply pressed upon it, and then rolled on paper. Thus the impression it left was a cylindrical projection of the whole bulb of the thumb, extending nearly from one side round to the other (fig. 8), and including all the principal characteristics of the pattern, which a simple impression (see those in Plate 2) often does not. The thumbs were easily cleaned by dipping them into a dish of turpentine and wiping with a cloth. It is an essential condition for making clear impressions that the ink should not lie low down the sides of the ridges. The furrows should remain quite uninked. I had much difficulty at first in contriving a rough and ready method of obtaining good impressions, and do not say that the plan just described is the best. But it has acted well for a long time, and, therefore, it is hardly necessary for me to speak here of later experiments to improve it.

Reversal of Patterns.

Patterns of similar kinds lie on the two thumbs in opposite directions. They should never be read from right to left, but from outwards, inwards. Consequently, in order to make the pattern on the one thumb comparable with that on the other, it must be reversed. It is convenient to take a duplicate of the impressions upon tracing cloth, which shows the reversed pattern when it is viewed face downwards.

Origin of the Patterns.

The reason why the patterns appear on the bulbs of the thumb and finger is apparently to be found in the presence of the thumb nail, which disarranges the otherwise parallel course of the ridges in the way that is diagrammatically shown in fig. 1.

Here we see that the upper ridges near the tip of the thumb are thrown into bold arches, while the ridges that lie below the level of the nail run horizontally. There is, in consequence, a tendency to leave an interspace, which has somehow to be filled up with a scroll work of ridges, and this scroll work constitutes the patterns with which we are concerned.

In about one case in thirty, the interspace is avoided by an arrangement like that in *a*, figs. 7 and 9, but this is an unstable form, or it often shows signs of having been on the point of breaking into a different pattern, as will soon be explained more fully. I call these patterns "Primaries," because they are the fundamental arrangement from which all the vast varieties of other patterns are lineally descended, and in all of which the interspace of which we have spoken exists.

Fig. 1.

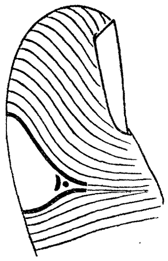


Fig. 2.

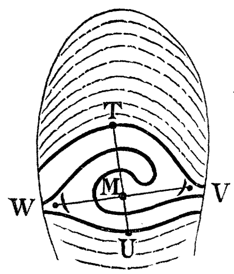


Fig. 3.

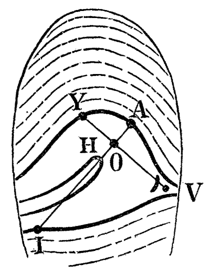
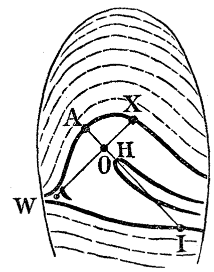


Fig. 4.



Points of Reference.

Wherever an interspace occurs, two ridges must have diverged in order to make room for it. There may be a divergence of the ridges on both sides of the interspace, as in fig. 2, or on one side only, as in figs. 3 and 4. Moreover, just in front of the place in the furrow, beyond which the parallel ridges begin to diverge, there are always one or more little cross lines, diagrammatically shown in all these figures, which cut off a small triangle.

The centres of these triangles form excellent spots or points of reference, though doubt may exist as to the exact position in which they should be placed. It is easy enough to determine their position approximately, and that is all we want.

Hereafter I shall always call these two points V and W. V being to the outside of the thumb, and W to the inside, that is to say, nearest to the rest of the hand. They are cardinal points in my classification, and are very useful in constituting the two ends of a base line (fig. 2) from which measurements may be made and bearings taken.

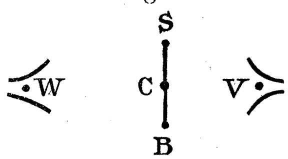
Reversals.

After the proper letters have been affixed to the points, it does not matter whether the pattern we are studying is direct or reversed. There is a curious variety in the way in which patterns are apt to be presented. Those on the right thumb are reversed forms of those met with on the left. The impression is the reversed form of the pattern itself. If made on a lithographic stone, it is re-reversed in the print. If made on transfer paper and thence put on the stone, it is re-re-reversed in the print. This is enough to show the confusion that will arise if the points V and W are not lettered, but it by no means exhausts the list of ordinary contingencies. As the letters V and W are unchanged in shape when they are reversed, they are convenient for the purpose to which they are here applied.

Basis of the Classification.

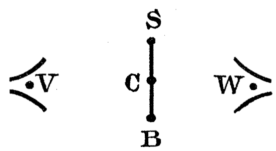
In one respect the divergent lines that bound the pattern admit, in the earlier part of their courses, of nine, and only nine, possible variations. Draw a line (figs. 5, 6) through what appears to be the most central part of the pattern (which we may call C), that shall be roughly parallel to the median line of the thumb, and shall cut

Fig. 5.



Print of left thumb, or appearance of face of right thumb.

Fig. 6.

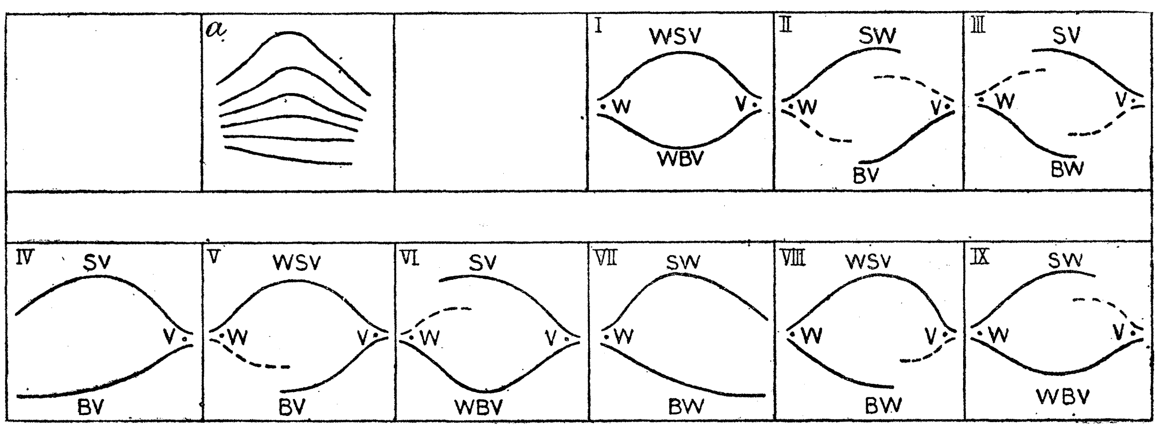


Print of right thumb, or appearance of face of left thumb.

the upper boundary of the pattern at S and the lower boundary at B. Consequently, S and B, whose positions are very roughly determined, may be taken to represent the summit and the base of the pattern. Now the ridge in which S is situated must, by construction, have come either from V or from W, or from both. There are these three, and only these three, alternatives, SV, SW, WSV. Similarly, as regards the ridge on which B is situated, there are the three alternatives, BV, BW, WBV. As any one of the former events may be combined with any one of the latter, there are 3 × 3, or nine possible combinations. In the primaries neither V nor W exist, so they form a class by themselves, making a total of ten classes. The nine of which we have been speaking are as follows :—

I. WSV—WBV	IV. SV—BV	VII. SW—BW
II. SW—BV	V. WSV—BV	VIII. WSV—BW
III. SV—BW	VI. SV—WBV	IX. SW—WBV

Fig. 7.



These, as well as the primary, which is distinguished by the letter *a*, are drawn in the diagram, fig. 7.

Outlines of the Patterns.

A pattern is quickly analysed by following with a pencil the course of the two pair of divergent ridges from V and W respectively (fig. 8), or if one of these points

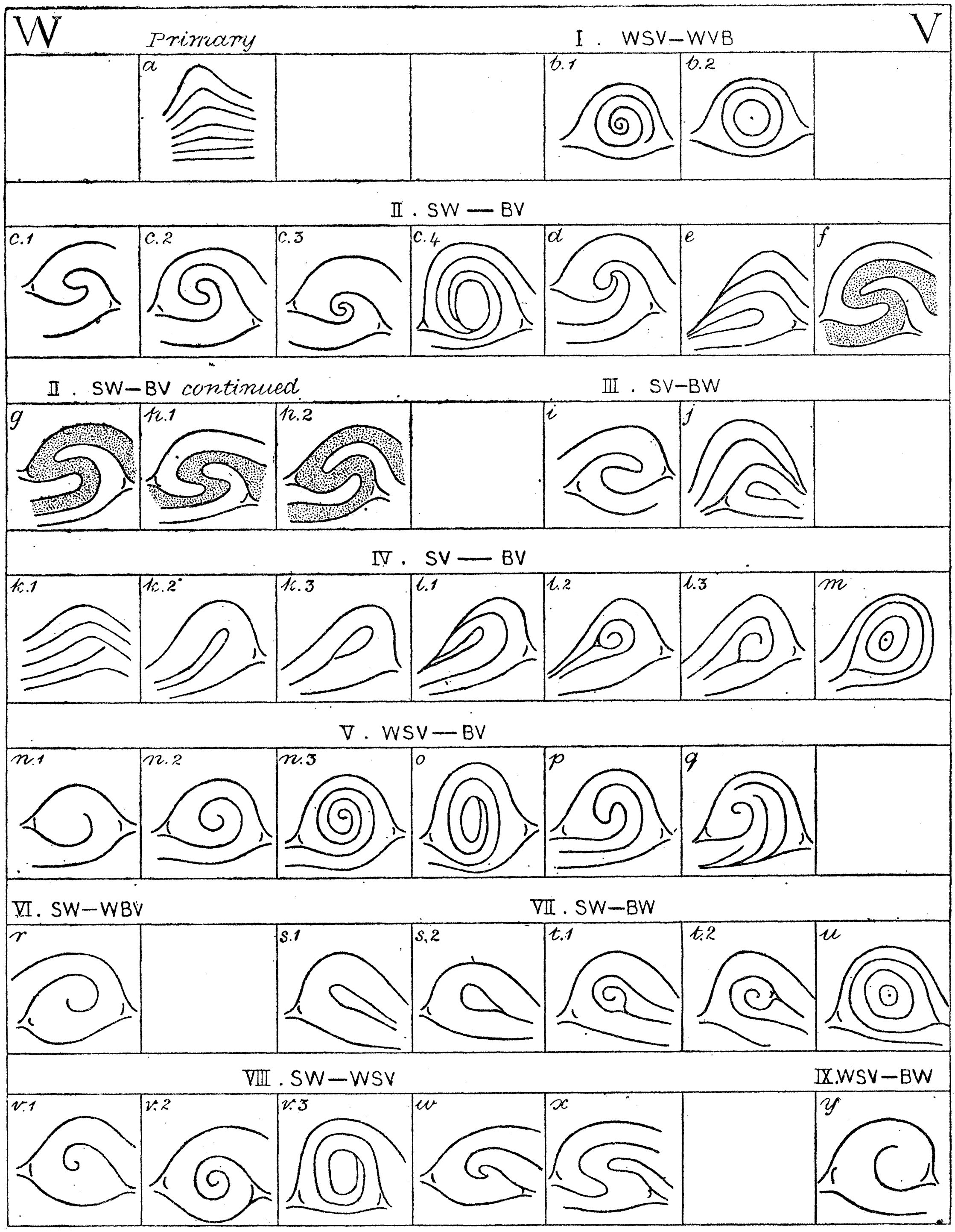
Fig. 8.

is absent, then following those that diverge from the other (see also figs. 2, 3, 4). As ridges are apt to bifurcate, to join with others, and also to end abruptly, it is necessary to follow a consistent course in such cases. In bifurcations the innermost branch should be followed. Whenever a ridge ends, the pencil should stop also, and recommence on a new ridge, selecting that which appears to continue the direction of the former one in the truest way. In case of doubt, the pencil should, as before, follow the innermost of the two lines between which the doubt lies. If opposite rules to these were imposed, the outline would be much less speedily analysed, and be by no means so simple when completed. The sudden transformation of a maze of ridges into an orderly pattern by this easy process is truly remarkable.

I outlined, where necessary, or otherwise examined, more than 1000 photographically enlarged impressions with much care, and found, on sorting them, that nearly all their patterns fell satisfactorily into one or other of the divisions in fig. 9, where twenty-five main divisions are arranged, according to the ten classes already described, namely, the primaries and the nine others. It must, however, be understood that, in sorting the impressions, no regard was paid in the first instance to other than essential points of difference. After this was done, some little regard was bestowed on secondary points, and a few of the species were subdivided by adding the numbers 1, 2, 3, &c., to their descriptive letter. For example, species *c* is subdivided into four groups, *c* 1, *c* 2, *c* 3, *c* 4, according to the amount of twist of the two belts of ridges of which it is composed, and to the presence or absence of a nucleus.

Marked instances of the occasional interpolation of a belt of ridges running from one side to the other through the pattern, and in a more or less tortuous course, occur in Class II. and correspond to the forms *f*, *g*, *h* 1, *h* 2. Such a belt often exists, but it is usually too narrow or ill defined to be worth regard. A pattern is sometimes composed altogether of such a tortuous belt, in which case it would rank along with the Primaries in Class *a*. As there are twenty-six letters of the alphabet, and only

Fig. 9.



twenty-five of them are used in fig. 9, the last letter, *z*, will serve to show that any pattern to which it is attached is *not* one of those in fig. 9.

All the patterns in fig. 9, are drawn on the supposition that W lies to the left and

V to the right. They are therefore those of impressions made by the left thumb, or of the ridges themselves as seen on the right thumb. The patterns must be read in a reversed sense, such as they would appear in a looking glass, to be applicable to impressions from the right thumb, or to the ridges themselves as seen on the left thumb.

Without professing to present a very complete epitome of the varieties, this table, (fig. 9) certainly provides a serviceable one, and may be looked upon as a convenient first step towards a more elaborate performance (fig. 8 would rank in it as *j* if W lay to the left, as *e* if it lay to the right).

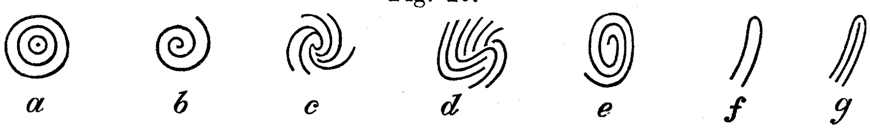
It must not be supposed that the occurrence of each of these representative patterns is equally frequent, such is very far indeed from being the case. The proportion of all the cases that falls under each of the ten classes varies between 1 and 65 per cent. About one half of all the specimens are of the pattern shown at *k* 2, which I call a *loop*, and nearly 25 per cent. are of one of those described as *c*.

It was mentioned that the descent of all the patterns can be traced from the primary. The first step in the evolution of the loop is seen in *k* 1, and that of the whorls is usually through the loop, as in *l* 1, *l* 2, &c., but sometimes it proceeds directly.

Nuclei.

The nucleus of a pattern may be of many varieties, and its form arrests the attention. I give a few diagrammatic patterns of the nuclei of whorls (*a* to *e*, fig. 10. Those of the loops present fewer varieties, the two principal of which are a central furrow, *f*, or a central ridge, *g*.

Fig. 10.



Exhibited Specimens.

I exhibit numerous impressions with or without the outlines of the patterns drawn upon them, some are photographically enlarged, others are impressed in printer's ink on glass, for use in the optical lantern. Besides these I exhibit some of the principal ways of making the impressions, as by first pressing the thumb or finger upon a piece of smoked glass, porcelain or mica, and then by transferring part of the soot that adheres to the ridges, to paper whose surface is gummed, sized, or varnished. I show also, a very convenient pocket apparatus for taking impressions at any time with printers' ink. I borrowed the main idea of this from Sir W. J. Herschel.

Identifying Patterns.

In identifying a pattern, we must bear in mind that the thumb which makes the impression is not a rigid body of invariable size and shape, but that the patterns it impresses at different times will vary. If those times are separated by long periods of growth or decay, the patterns may become much distorted. They may change their shape just as the pattern on different portions of the same piece of machine-made lace may become variously stretched by wear, or shrunk by wet, or even be torn. In comparing the patterns on two such portions, the evidence of their identity would chiefly lie in the number of threads that went to the making of corresponding parts of the pattern of the lace. So, in the impression of the thumb marks, the first point is to count the number of ridges that intervene between such points in the pattern as we may be able to define with sufficient precision for the purpose. The simplest way of doing this for descriptive purposes, would be to mark a few appropriate points on each of the patterns in fig. 9 with the letters, A, B, C, &c. Then it would give a clear description of the larger peculiarities of a particular pattern, to say that it was of the general pattern so and so, and that the number of ridges between A and B, C and D, &c., was so and so, respectively. I shall have occasion in this paper to use two methods of reference and measurement, which had best be described now.

First, suppose V and W both to exist (fig. 2). Then join VW, bisect it at M and draw a perpendicular through M, meeting the upper boundary in T and the lower in I.

Secondly, suppose only V to exist (fig. 3). In this case the curve must be of the loop form, which almost always has a well marked axis determined by the direction of the upper end of the innermost bend of the loop. There is usually quite enough length in a straight line of the uppermost portion of the inner bend to indicate the direction of the desired axis, which meets the upper boundary of the pattern at A, and the lower at I. Let fall a perpendicular from V on to this axis, cutting it at O, and meeting the opposite boundary at Y.

Thirdly, suppose only W to exist. Then proceed just as before, substituting the letter W for V, and calling the point where the prolongation of WO meets the opposite boundary, by the letter X instead of Y.

The cross lines in these three figures will serve the same purpose as the cross lines of the compass card marked upon a map. In two of the three cases W is present, which letter, since it suggests west, may be designated by the numeral 24, which is the number expressing the west point of the compass, N being 0 (or 32), and S being 16.

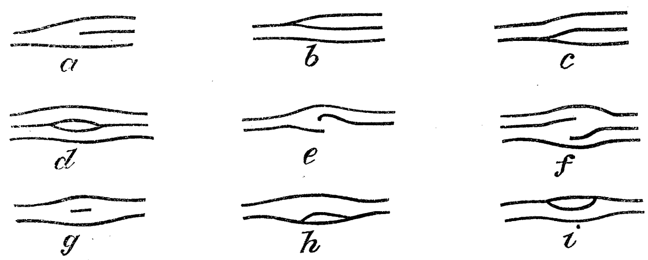
In the other two cases V is present. By parity of nomenclature V would always be designated by 8. Then T or A, as the case may be, is designated by 0 (or 32), and U or I by 16. The intermediate points will be numbered accordingly. This nomenclature, it will be observed, serves equally well for the right or left thumb, and for either direct or reversed impressions of them.

Identifying Minutiæ.

The patterns on the thumb have just been compared to those on lace which may be variously shrunk or stretched, but in which the number of threads that are used to form each detail of the pattern remains unaltered. The simile may be further extended by supposing the thread to have been variously irregular and divided. Then the position of its several irregularities in respect to the parts of the pattern would remain unchanged, although the shape of the piece of lace as a whole may have greatly altered.

The minutiæ about to be described form minor patterns of their own, quite distinct from the larger patterns shown in fig. 9. They are chiefly connected with the commencements of interpolated ridges. At or about a particular spot in the pattern two ridges that had previously run in parallel and adjacent courses are replaced by three ridges (fig. 11). This is the main fact to be noticed. The particular way in which

Fig. 11.



the two ridges seem to have been converted into three is by no means so important, because its appearance is often false and misleading. The conversion may have been affected either by a new ridge arising between two others which diverge so as to yield place to the intruder, as in fig. 11*a*, or else by one of the two ridges bifurcating, as in *b* and *c*.

But grave difficulties not unfrequently arise in distinguishing between these three cases. One impression may show one form, and another impression taken immediately afterwards from the same thumb may show another. The reason is that the ridges are not of a uniform height and that the head of the fork is often low, and fails to leave its mark on one of the prints, though it does so on the other. Thus neither of the two cases *b* and *c* admits of being certainly distinguished from *a*. This kind of difficulty is frequent where a ridge momentarily divides so as to enclose a small crater as in *d*. One lip of the crater may leave no mark, and the impression of *d* might have the appearance either of *e* or of *f*. Similarly as regards islands, as in *g*, *h*, and *i*.

These remarks are intended as a caution against placing too much trust in the specialities of these appearances, though usually the distinction between a fork and the beginning of a new ridge is clear enough.

Persistence of Patterns.

I submit the impressions in Plate 1 in justification of the conclusions to be drawn from them. They were all furnished to me by the kindness of Sir W. J. HERSCHEL, who, when employed in the Indian Civil Service in Bengal many years ago, introduced in his district the practice of taking impressions from the first two fingers of the right hands of witnesses and others as a check against personation. I also possess photographs of some other impressions besides those in Plate 1, taken from other fingers of some of the same persons, and which tell a similar tale.

Each of the eight double sets in Plate 1 consists of two impressions of the same digit of the same person, taken at the beginning and end of a long interval of years. In six of the eight double sets the impressions are those of two different fingers of three different persons. In the remaining two the impressions are of one finger of two different persons. The entry 1 *r* means the forefinger of the right hand, 2 *r* its middle finger, 3 *r* its third finger. The cases 1 and 2 refer to a youth who was a child of seven and a half years old when the first impression was taken; this was nine years previous to the second impression. The remaining six cases refer to four men who were adults when the first impression was taken, and this occurred at a period varying between twenty-eight and thirty-one years before the second impression. The photographs of all these impressions are enlarged to twice their natural size for the greater convenience of reference, and every point suitable for comparison in each pair of impressions has been examined and noted in Plate 2. It is rare that the one impression presents quite the same portion of the pattern as its fellow. Also it occasionally happens that a portion of one impression is blotted or otherwise too imperfect to allow of fair comparison with the corresponding portion of the other. Subject to these necessary restrictions every fork, junction, crater, or island in each impression has been noted, and in every single case has been found to occur in both the members of the same pair, subject only to the reservations previously made, that is to say, what appears as a fork in a first impression sometimes appears as the independent interpolation of a new ridge in the second, or *vice versâ*. I have in these cases reckoned it as being of similar appearance in both, and have marked it with the same symbol in both of the skeleton charts, viz., by a fork or by a dot, selecting between the alternative symbols the one that appeared on the whole to be most suitable.

No. on the Plate.	Initials.	Digit.	Age at date of first impression.	Date of the first impression.	Date of the second impression.	No. of years interval.	No. of beginnings and ends of ridges.	No. of forks and junctions of ridges.	Total No. of points of comparison.
1	A.E.H.	1 *r*	$7\frac{1}{2}$	1881	1890	9	19	14	33
2	A.E.H.	3 *r*	$7\frac{1}{2}$	1881	1890	9	18	18	36
3	N.H.T.	1 *r*	adult	1862	1890	28	16	11	27
4	N.H.T.	2 *r*	adult	1862	1890	28	17	19	36
5	F.K.H.	1 *r*	adult	1862	1890	28	27	28	55
6	R.F.H.	2 *r*	adult	1859	1890	31	10	17	27
7	W.J.H.	thumb *r*	adult	1860	1890	30	18	32	50
8	W.J.H.	3 *r*	adult	1859	1890	31	15	17	32
	Grand totals						140	156	296

I did my best to justly reckon the number of minutiæ in each impression that admitted of comparison, but found it difficult; perhaps it is impossible to be absolutely accurate.

Other persons may make estimates that differ slightly from mine, but mine are, I am sure, substantially correct and trustworthy for all practical purposes. I counted as separate points both of the ends of every island, however short the island might be, and both of the forks that enclosed every crater however minute.

The upshot of a careful step by step study is that I have found an absolute and most extraordinary coincidence between the details of each of the two impressions of the same finger and of the same person. There was, as the table shows, a grand total of no less than 296 (say, roundly, 300) points of comparison, and not a single one of them failed, though I had much trouble in deciphering the ridges, especially about the V-point in case 5. There was no one case found of a difference in the number of ridges between any two specified points. Never during the lapse of all these years did a new ridge arise, or an old one disappear. The pattern in all its minute details persisted unchanged, and, *à fortiori*, it remained unchanged in its general character.

[January 28. Since writing this memoir, I have had opportunities of making a considerably larger total of comparisons between other pairs of impressions, and I have thus far found one instance, and one instance only, of any fundamental disaccord. It was a ridge that had been partially cleft in a child, but when he had grown into a boy the cleft had disappeared.]

The comparison would, however, present discrepancies and be much less effectively carried on if it were performed by first registering the observed peculiarities of one pattern, next those of the other, and, lastly, comparing the two registers. Each would be likely to contain points in which the other was deficient, and not a few very characteristic features might be overlooked in both. For example it will be seen in the two impressions, No. 2 in the skeleton chart, that I have inserted an arrow head to draw attention to a small spot a little in front of it, which represents an isolated papilla. This spot would have been passed over as a mere accident of the ink, unworthy of record, had it not been that, in making the comparison from point to point, the same dot was observed in both impressions. It was then recognised to be of importance. It is pretty to notice how the small dot in the child has grown to a larger dot in the youth.

The lapse of about thirty years is seen in these eight examples to have introduced no fundamental difference in the patterns of four different adults, nor has the lapse of nine years, during the period of growth from childhood to youth, done so in a fifth person. The patterns often have become broadened and variously distorted, especially in case 6; but in respect to those characteristics, on which alone I have laid any stress, there has been no change whatever.

It appears that the ridges make their first appearance in the fourth month of fœtal life, and to be fully and finally developed in the sixth month, for they then seem to possess the same degree of complexity of structure that exists in the patterns of adults. Putting all together, we may fairly infer that, from birth to death, there is no change in the fundamental characteristics of the thumb and finger patterns, nor can there be any after death up to the time when the skin perishes through decomposition.

The popular idea that has hitherto been jumped at, without adequate evidence,* is now shown to be strictly correct on very good evidence and after careful inquiry. There appear to be no means of personal identification other than deep scars and tattoo marks, comparable in their permanence and certainty with those of the thumb and finger marks. All the dimensions of the limbs alter in the slow course of growth and decay. The colour of the hair, the quality and tint of the skin, the expression of the features, the gestures, the handwriting, even the eye colour, change after many years. There seems to be no persistence anywhere in the bodily structure, except in these minute and too much disregarded papillary ridges.

Scars.

The question remains to be considered as to how far the patterns may be affected by scars, or obliterated by rough usage. I find that, of the 2500 or more persons whose thumbs have been impressed at my small Anthropometric Laboratory at South Kensington, the patterns are rarely destroyed to any considerable degree. I have to search through hundreds of thumb marks to find an instance of even a small scar. Partial obliterations are more frequent, but here, though much is lost, a sufficiency remains; and if the thumb is rolled and not only pressed, more would be available. If the fingers had been rolled in making the impressions in Plate 2, there would have been perhaps twice as many points of comparison, for the areas they represent would have been twice, or nearly twice as great as they are now, and the number of points suitable for comparison would have been proportionately increased.

Analogy between the Classes and Ordinary Genera.

We have seen that the peculiarities which distinguish the classes of the patterns are fundamentally distinct. It might thence be inferred that the class of any given pattern would be clearly distinguishable. But this is not invariably the case. A characteristic, however fundamental in its character, may be so poorly developed in a particular case, as to be overlooked, or be barely, if at all, traceable.

* Subsequent inquiry confirmed the opinion expressed in my lecture at the Royal Institution, referred to above, that an often repeated assertion to the effect that impressions of the hand are used in Chinese prisons for purposes of identification, is erroneous. The impression of the finger in China, as elsewhere in the East, is sometimes affixed to documents merely as a ceremony of personal contact, much as the witnesses in an English court of law are required to hold and to kiss the Bible on which they are sworn.

A core as in *b*2, fig. 9, belongs to a WSV—WBV class, while a core that is enclosed in a loop, as *m*, belongs to a SV—BV, or one as *u*, to a SW—BW class. But the enveloping loop may be so narrow as to be overlooked. Nay, it may consist of but a single ridge, and that ridge may not make the complete circuit, but either stop by the way or form a junction with the outer ridge of the core. Transitional cases of this sort may and do occur, and they might conceivably occur frequently.

There are perhaps no two classes that might not be in some way connected by transitional cases, though it may often be difficult to imagine how. We are not justified in denying either the possibility or the frequency of any such transitional form on purely *à priori* grounds, but must appeal to observation, which assures us that they are rare.

In order to rightly understand the degree and the way in which any class of pattern is isolated, it is necessary to study a large number of specimens, consequently, as loops are so numerous, we cannot do better than to base the discussion upon them, and learn whether or no the individual variations of loops cluster around a central or typical form, or whether they are distributed in any other way. We must study the peculiarities of the loop separately and in detail, and the best detail for our purpose is the number of ridges in AH, where H is the point in the innermost bend of the loop at which it is cut by AI (see figs. 3 and 4).

The ridges in AH are easily counted because AH cuts them squarely, owing to the construction of the figure. I took a number of specimens of loops, in the order in which they came to hand, and had the number of ridges in AH counted in each loop. (I had also, myself, previously made more than one independent trial on a considerable scale, but the specimens had not been those of a strictly random selection, and I thought best not to use them).

The ridge at A was counted as 0, the next ridge as 1, and so on up to H. Whenever the line AH passed across the neck of a bifurcation, so that there was one ridge fewer on one side of the point of intersection than on the other, there would clearly be doubt whether to reckon it as 1 or as 2 ridges. A compromise had, therefore, to be made by counting it as $1\frac{1}{2}$. After the number of ridges in AH had been counted in each case, all residual fractions of $\frac{1}{2}$ were alternately treated as 0 and as 1. In a very few cases there was doubt whether to classify a pattern that approximated to *k* 1, as a loop, the number of whose ridges in AH was 0, or even 1, or whether to consider it as a Primary, *a*.

It is more convenient to work from the results when given in the form of the percentages, which will be found in Table I., and where the number of cases from which the percentages were made is entered at the top. It is quite unnecessary to work more closely than to the nearest integer. We see at a glance that the different numbers of ridges in AH do not occur with equal frequency, that 1 ridge is a rarity, and so are cases of ridges above 15 in number, but that the cases are frequent of 7, 8, and the neighbouring numbers of ridges. There is clearly a rude sort of order in their distribution, the cases being more numerous for median values, and tailing away into nothingness at the top and bottom of the column. A vast amount of statistical analogy assures us that the orderliness of the distribution would be increased if the cases observed had been much more numerous. Later on this inference will be corroborated. There is a sharp inferior limit to the numbers of ridges, because they cannot be less than 0, but independently of this, we notice the growing infrequency of small numbers as well as of large numbers of them. There is no strict limit to the latter, but the trend of the figures convinces us that say, 40 or more ridges in AH are practically impossible. Therefore, no individual number of ridges in AH can possibly depart very widely from the observed average numbers of ridges in AH; but the range of possible departures is not sharply limited, except at its lower margin. Their possibilities are not "rounded off," to use a common but very misleading expression that is often applied to the way in which genera are isolated. The range of the possible departures in the case of genera is not suddenly and sharply restricted, but the rarity of the stragglers from the average form rapidly increases with the degree of their departure, until no more of them are met with.

TABLE I.

No. of ridges in AH.	No. of cases reduced to per cents.		VY/OI.	No. of cases reduced to per cents.		AO/AH.	No. of cases reduced to per cents.	
	Left.	Right.		Left.	Right.		Left.	Right.
	171 cases.	166 cases.		149 cases.	140 cases.		176 cases.	163 cases.
1	..	1	0·3–0·4	2	3	0·1–0·2	1	2
2	1	2	0·5–0·6	11	8	0·3–0·4	3	7
3	3	2	0·7–0·8	14	9	0·5–0·6	3	11
4	5	2	0·9–1·0	18	21	0·7–0·8	9	9
5	5	3	1·1–1·2	23	16	0·9–1·0	15	22
6	18	4	1·3–1·4	7	24	1·1–1·2	13	15
7	14	8	1·5–1·6	10	8	1·3–1·4	12	12
8	16	8	1·7–1·8	6	3	1·5–1·6	14	11
9	10	11	1·9–2·0	6	5	1·7–1·8	10	8
10	8	9	2·1–2·2	1	1	1·9–2·0	5	1
11	10	14	above	2	2	2·1–2·2	..	..
12	8	11	..	..	..	2·3–2·4	6	1
13	2	10	..	..	..	2·5–2·6	4	..
14	..	7	..	..	..	2·7–2·8	3	..
15	..	6	..	..	..	2·9–3·0	1	..
above	..	2	..	..	..	above	1	1
	100	100		100	100		100	100

It is convenient to discuss these and similar cases in the way adopted in Tables II. and III. These show how far the distribution of the observed cases conforms to the well-known theoretical law of Frequency of Error. If they conform to it fairly well, we are justified in speaking of a central or typical number of ridges in AH, and of considering any other number of ridges as a departure from that typical and central value.

TABLE II.

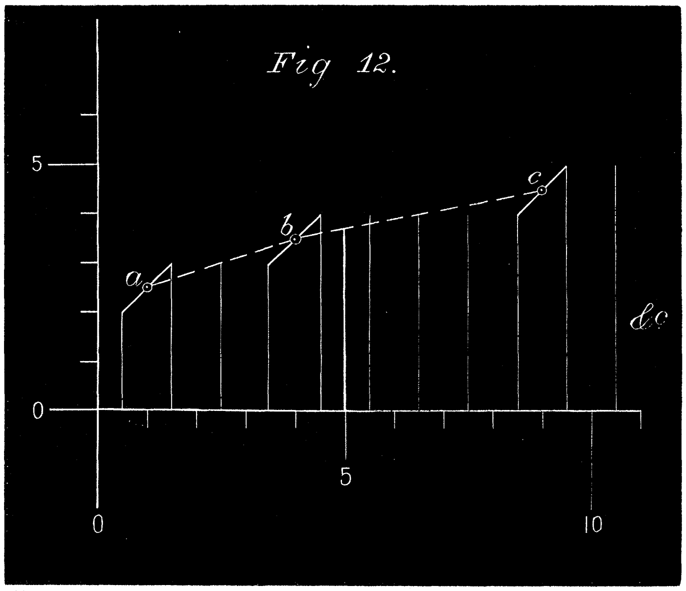
Abscissæ reckoned in centesimal parts of the interval between the limits of the scheme. 0 to 100.	Ordinates to the six schemes of Distribution, being the ordinates drawn from the base of each scheme at selected centesimal divisions of the base.											
	No. of ridges in AH.				Values of VY/OI.				Values of AO/AH.			
	Left.		Right.		Left.		Right.		Left.		Right.	
	Observed.	Calculated from M = 7·8 p.e. = 1·9	Observed.	Calculated from M = 10·4 p.e. = 2·3	Observed.	Calculated from M = 1·10 p.e. = 0·31	Observed.	Calculated from M = 1·15 p.e. = 0·25	Observed.	Calculated from M = 1·36 p.e. = 0·36	Observed.	Calculated from M = 1·08 p.e. = 0·30
5	3·8	3·2	3·8	4·8	0·49	0·35	0·54	0·54	0·58	0·48	0·36	0·32
10	4·8	4·2	5·5	6·0	0·59	0·51	0·64	0·67	0·74	0·68	0·50	0·48
20	5·8	5·4	7·3	7·5	0·78	0·71	0·85	0·84	0·96	0·91	0·66	0·67
25	6·1	5·9	7·9	8·1	0·83	0·79	0·91	0·90	1·00	1·00	0·79	0·75
30	6·4	6·3	8·5	8·6	0·89	0·86	0·99	0·95	1·04	1·08	0·87	0·82
40	7·1	7·4	9·5	9·5	1·00	0·98	1·05	1·05	1·21	1·22	0·98	0·93
50	7·8	7·8	10·5	10·4	1·10	1·10	1·15	1·15	1·37	1·36	1·04	1·05
60	8·4	8·2	11·3	11·3	1·18	1·22	1·29	1·25	1·48	1·50	1·18	1·17
70	9·3	9·3	12·1	12·2	1·32	1·34	1·33	1·35	1·66	1·64	1·31	1·28
75	9·9	9·7	12·5	12·7	1·46	1·41	1·41	1·40	1·73	1·72	1·39	1·35
80	11·0	10·2	13·0	13·3	1·53	1·49	1·45	1·46	1·90	2·81	1·48	1·43
90	11·5	11·4	14·3	14·8	1·73	1·69	1·77	1·63	2·23	2·04	1·69	1·62
95	12·2	12·2	15·0	16·0	1·80	1·85	2·00	1·76	2·48 about	2·24	1·81	1·78

TABLE III.

Abscissæ reckoned in centesimal parts of the interval between the limits of the curve. 0 to 100.	Ordinates to the six curves of distribution drawn from the axis of each curve at selected centesimal divisions of it. They are here reduced to a common measure, by dividing the observed deviations in each series by the probable error appropriate to the series and multiplying by 100. For the values of M, whence the deviations are measured, and for those of the corresponding probable error, see the headings to the columns in Table II.						Mean of the corresponding ordinates in the six curves after reduction to the common scale of p.e. = 100. 965 observations in all.	Ordinates to the normal curve of distribution, probable error = 100.
	No. of ridges in AH.		Values of VY/OI.		Values of AO/AH.			
	Left.	Right.	Left.	Right.	Left.	Right.		
5	−211	−291	−196	−244	−217	−230	−231	−244
10	−158	−213	−164	−204	−172	−183	−182	−190
20	−105	−135	−103	−120	−111	−130	−117	−125
25	− 84	−109	− 87	− 92	−100	− 87	− 93	−100
30	− 74	− 83	− 68	− 64	− 89	− 60	− 73	− 78
40	− 37	− 44	− 31	− 44	− 42	− 23	− 37	− 38
50	0	+ 4	0	0	0	0	+ 1	0
60	+ 31	+ 39	+ 23	+ 56	+ 33	+ 43	+ 38	+ 38
70	+ 79	+ 74	+ 68	+ 72	+ 83	+ 87	+ 77	+ 78
75	+116	+ 91	+116	+104	+103	+113	+107	+100
80	+168	+113	+138	+120	+150	+143	+139	+125
90	+200	+170	+203	+248	+242	+213	+213	+190
95	+231	+200	+225	+340	+311	+253	+260	+244

The method used here is one that I have often described, but I fear I must briefly describe it again because it is not generally understood, though it is already beginning to be used by anthropologists and others. The 100 cases (the percentages in Table I.) that refer, say, to the left thumb are entered upon a piece of paper ruled by 101 vertical lines, numbered from 0 to 100, which divide any horizontal line into 100 equal and horizontal spaces. It appears from the table that we may have to deal with various numbers of ridges from 0 up to 15, so there must be 16 horizontal lines at equal distances apart, and numbered from 0 to 15, enclosing 15 equal vertical spaces.

The table begins by telling us that out of the 100 cases there are 1 of two ridges, 3 of three ridges, 5 of four ridges, and so on. These values are entered on the ruled paper by erecting, (fig. 12,) one ordinate reaching to the second line in the middle of the



first space; three ordinates reaching to the third line and severally standing in the middle of each of the next three spaces (which, counted from the beginning, are the second, the third, and the fourth); five ordinates reaching to the fourth line and severally standing in the middle of each of the next five spaces; and so on, until all the 100 spaces have been utilized for the 100 tabular entries. Then a curve may be drawn with a free hand through the tops of the 100 ordinates, and the figure called a Scheme of Distribution is thereby produced. But there is an objection to free hand curves, in the temptation to draw them too smoothly. Therefore I do no more than unite with straight lines, as shown in fig. 12, the halfway points *a*, *b*, *c*, &c. between each successive step. The 100 ordinates have now served their purpose, and being in the way, had better be rubbed out (practically they are never drawn), leaving only the curve, the divisions between which the ordinates were or were supposed to be drawn, and the side scale.

New ordinates to the curve are now erected at the convenient divisions of the base given in the first columns of Tables II. and III. (see the broad white line corresponding to 5 in fig. 12). They are measured, and their lengths are recorded, and may at any future time be again mapped down in order to form a skeleton by which to reproduce the original scheme. The lengths of these interpolated ordinates are given in the column of Table II. headed "Observed." Being interpolations, they do not consist, except by chance, of an integral number of ridges. But fractional values are not meaningless; they have already been employed whenever AH cuts the neck of a fork.

The ordinate at the 25th division of the base, called Q_1, cuts off the lower quarter of the scheme; the ordinate at the 75th, called Q_3, cuts off the upper quarter. Half the difference between them, or $\frac{1}{2}(Q_3 - Q_1)$, is called the Quartile, and is expressed by Q. It measures the "probable" dispersion (in the sense of "probable error") of individual values from the value of $\frac{1}{2}(Q_3 + Q_1)$, which is called M′.

In a symmetrical curve M′ is identical with the ordinate at the 50th division, in other words, with the median value of all the ordinates in the series, and is called M. Further, in a symmetrical curve, the median M is identical with their arithmetic mean value. In the six different series contained in Table II., and in numerous analogous ones that I have worked out elsewhere, the values of M′ and of M are nearly identical. Whenever they differ, I have taken an intermediate value that is nearer to M than to M′. This correction has been always very trifling. The values of M and Q for each of the series with which we are concerned, are given at the heads of the second of each pair of columns in Table II.

The next step is to change from the Scheme to the Curve that bounds it; the ordinates are measured henceforth from the axis of the curve, up or down as the case may be. The axis is a line drawn parallel to the base of the scheme, which cuts the curve at the point where it was met by M; that is by the ordinate erected at the 50th division of the base.

The axis is divided into 100 divisions just like the base. The ordinates of a curve of this description, not founded on any observations, but wholly on the theoretical law of Frequency of Error, can be deduced from the well-known tables of the Probability Integral. They, and the curve itself, may be conveniently spoken of as "Normal."

The few ordinates of the normal curve with which we are concerned will be found in the last column of Table III. There the quartile (= probable error) is taken as 100 and not as 1, in order to avoid decimals in the tabular entries, which are restricted to three figures each.

When preparing to compare the ordinates of a curve drawn from observation with those of a normal curve, we must first multiply the ordinates of the normal curve, whose quartile (or probable error) = 100, by the value of the quartile of the observed curve. Or, conversely, if we wish to compare the ordinates of the normal curve whose quartile = 100, with those of the observed curve, we must first divide those of the observed curve by the value of their own quartile, and then multiply them by 100. The latter process has been adopted in Table III.

There is yet another useful step. Given the values of M and Q we may calculate the value of any ordinate in the scheme, by the help of the values of the normal ordinates to the curve given in the last column of Table III., and collate the calculated with the observed values. This has been done in Table II.

We will first consider the results shown in Table II. It is seen that the accordance between the calculated and observed number of ridges in AH, in the left and in the right thumbs severally, is respectably close. Considering the paucity of the observations, which are only 171 in the one case and 166 in the other, there is nothing in the results that contradicts the possibility of a much closer conformity when very many more observations are dealt with.

Precisely the same process has been gone through in respect to the values of the fractions of VY divided by OI (see fig. 3), which is practically the breadth of the loop divided by its length. The results are of a similar character to those yielded by the numbers of ridges in AH.

Again, I have tried the fraction of AO divided by AH, and still the results are found to be of the same kind.

Now turning to Table III. I there obtain a general average result from all of the three double sets, by an artifice. Each observed series of departures from the axis of the curves is reduced to what it would have been if the unit of the scale by which its departure had been measured, was equal to its own quartile multiplied by 100. In short, every one of the ordinates in each series was divided by the value of the quartile of that same series, and then multiplied by 100. Their average results are given in the last column but one, and the corresponding normal values in the last column. The orderly run of the figures is much closer now than it was in any one of the six separate series because they are derived from many more observations, namely, 965 of them.

We also see that though there is an obvious want of exact symmetry in the ordinates of the observed curve, their general accord with those of the normal curve is very fair. It is quite close enough to establish the general proposition that we are justified in relying upon the ideal conception of a typical form of loop, different for the two thumbs, from which individual loops differ. That the departure from the typical form is usually small, rarely rather greater, and very rarely indeed rather greater still.

It would be tedious to enumerate the many different trials that I have made for my own satisfaction, in order to assure myself that the variability of the several patterns was really of the quasi-normal kind just described. In my first trial I measured in various ways the dimensions of about 500 enlarged photographs of loops, and about as many of other patterns, and found that the measurements in each and every case formed a quasi-normal series. I do not care to submit these results, because they necessitate more explanation and analysis than the interest of the corrected results would, perhaps, justify, to eliminate from them the effect of variety of size of thumb, and some other uncertainties. Those measurements referred to some children, a few women, many youths, and a fair number of adults; and allowance has to be made for variability in stature in each of these classes.

The proportions of a typical loop are easily ascertained if we may assume that the most frequent values of its variable elements, taken separately, are the same as those that enter into the most frequent combination of the elements taken collectively. This would necessarily be true if the variability of each element separately, and that of the sum of them in combination, were all strictly normal, but as they are only quasi-normal the assumption must be tested. I have done so by making the comparisons shown in Table IV., which come out correctly to within the first decimal place.

TABLE IV.

	Left thumb.	Right thumb.
(*a*) Median of all the values of VY . . .	10·1	12·5
(*b*) Median of all the values of OI . . .	8·9	10·1
Value of a/b	1·11	1·24
Median of all the fractions VY/OI . .	1·10	1·15
(*c*) Median of all the values of AO . . .	4·6	4·6
(*d*) Median of all the values of AH . . .	3·3	4·4
Value of c/d	1·40	1·05
Median of all the fractions AO/AH . .	1·36	1·08

They show that it is practically the same thing whether we take the fraction, which is the median of all the fractions, or whether we take the fraction whose numerator is the median of all the numerators, and whose denominator is the median of all the denominators. I have used the medians here and throughout this inquiry instead of the arithmetic means, but an inference like the foregoing which is based on the medians, may be accepted without cavil as being equally true of the means.

This being premised, the proportions of the typical loop are to be taken as follows :—

	Left thumb.	Right thumb.
Length of OA in millimetres	4·6	4·6
,, OI ,,	8·9	10·1
,, OV ,,	7·6	8·3
,, OY ,,	3·1	4·2
,, AH ,,	3·3	4·4
Number of ridges in AH	7·3	9·9
Mean breadth of one of the ridge intervals in AH	0·46	0·45

As absolute measures, the above are too small for the average adult male and too large for the average adult female, but as proportions they are correct.

I do not see my way to discuss the primaries on the same general lines as the loops, because they possess no distinct points of reference. But their general appearance does not give the impression of clustering around a typical centre. They seem rather to suggest the idea of the head of a stream, that begins to diverge from the first.

As regards other patterns, I have made many measurements altogether, but the specimens of each sort were comparatively very few, except in *c* patterns. In all cases where I was able to form a well-founded opinion, the existence of a typical centre was indicated. It was not necessarily or usually the same in the two thumbs ; indeed, there is a curious difference between their patterns, into which I do not propose to enter here.

There is reason to believe that the patterns are hereditary. I have no adequate amount of data whereby to test the truth of this belief by a direct inquiry, but rest the belief partly on analogy, but more especially on the ascertained existence of a considerable tendency to symmetry. When, for instance, there is a primary pattern on one thumb, there are not far from ten chances to one in favour of its been found on the other. Again, if there is a loop in one thumb, there is a strong chance that it will be found in the other thumb also. Similarly as regards each pair of corresponding fingers. Therefore the causes of the pattern must not be looked for in purely local influences. Part of the causes why it and not another pattern is present, are common to both sides of the body and may therefore be called constitutional, and be expected to be hereditary.

Accepting, then, the hypothesis that the patterns are to some extent hereditary, we possess in them an instructive instance of the effects of heredity under circumstances in which sexual selection has been neutral. The very existence of the patterns has been hitherto almost overlooked, because they are too small to attract attention, or thought too uninteresting to notice. Neither do they appear to be correlated with any desirable or repellent quality. It is true that the breadth of a ridge-interval may afford a direct indication of the delicacy or the reverse of the sense of touch, as measured by the just discernible distance between compass points, and some indirect indication of the sensibility generally. (I do not know that it is, but have planned experiments for testing the supposition.) Yet, even if so, the fact would have no bearing on the attractiveness or otherwise of any particular pattern, because the form of a pattern has nothing to do with the fineness or coarseness of the ridges that compose it. There has, therefore, been complete promiscuity of marriages, or, as it is now called, panmixia, in respect to these patterns. We might consequently have expected them to be hybridised. But that is most assuredly not the case; they refuse to blend. Their classes are as clearly separated as those of any of the genera of plants and animals, while we happen to know enough about their origin to understand that this must be the case, inasmuch as they are intrinsically different. Each of the patterns keeps as pure and distinct from the others as if they had been severally descended from a thorough-bred ancestry, each in respect to its own peculiar form.

As regards the influence of all other kinds of natural selection, we know that they co-operate in keeping races pure by their much more frequent destruction of the individuals who depart the more widely from the typical centre. But natural selection is wholly inoperative in respect to individual varieties of patterns, and unable to exercise the slightest check upon their vagaries. Yet, for all that, the different classes of patterns are isolated from one another, through the rarity of transitional cases, just as thoroughly, and just in the same way, as are the genera of plants and animals. There is no statistical difference between the form of the law of distribution of individual patterns about their respective typical centres, and that of the law by which, say, the Shrimps described in Mr. WELDON's recent memoir ('Roy. Soc. Proc.,' vol. 47, p. 445) are distributed about theirs. In both cases the distribution is in quasi-accordance with the theoretical law of Frequency of Error, and this form of distribution is caused in the case of the patterns entirely by internal conditions, and in no way by natural selection in the ordinary sense of that term.

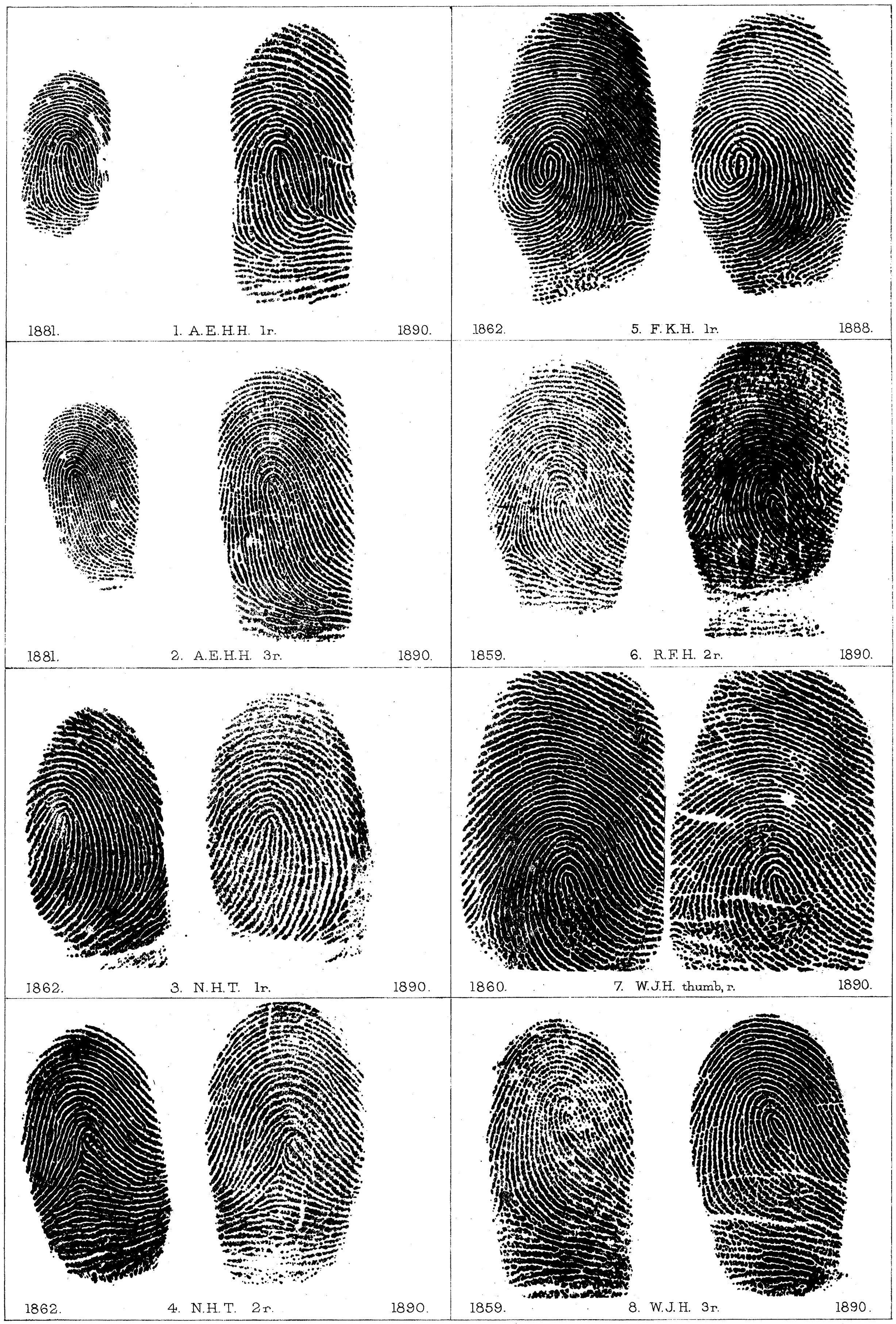
It is impossible not to recognise the fact so clearly illustrated by these patterns in the thumbs, that natural selection has no monopoly of influence in forming genera, but that it could be wholly dispensed with, the internal conditions acting by themselves being amply sufficient to form them. When the internal conditions are in harmony with the external ones, as they appear to be in all long-established races, their joint effects will curb individual variability more tightly than either would do by itself. The normal *character* of the distribution about the typical centre will not be thereby interfered with. The probable divergence (= probable error) of an individual taken at random will be lessened, and that is all.

Not only is it impossible to substantiate a claim for natural selection that it is the sole agent in forming genera, but it seems, from the experience of artificial selection, that it is scarcely competent to do so by favouring mere *varieties*, in the sense in which I understand the term.

My contention is that it acts by favouring small *sports*. Mere varieties from a common typical centre blend freely in the offspring, and the offspring of every race whose *statistical* characters are constant, necessarily tend, as I have often shown, to revert towards their common typical centre. Sports do not blend freely; they are fresh typical centres or sub-species, which suddenly arise we do not yet know precisely through what uncommon concurrences of circumstance, and which observations show to be strongly transmissible by inheritance.

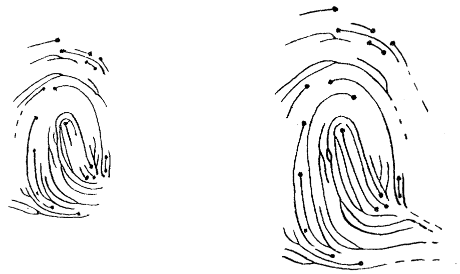
A mere variety can never afford a sticking point in the forward course of evolution, but each new sport implies a new condition of internal equilibrium, and does afford one. A change of type is effected, as I conceive, by a succession of sports or small changes of typical centre, each being in its turn favoured and established by natural selection to the exclusion of its competitors. The distinction between a mere variety and a sport is real and fundamental. I argued this point in a recent work ('Natural Inheritance,' Chapter III., MACMILLAN, 1889), but had then to draw my illustrations from non-physiological experiences. I could not at that time find an appropriate physiological one. The want is now excellently supplied by observations of the patterns made by the papillary ridges on the thumbs and fingers.

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES



West, Newman, Photo. lith.

Plate, I. Eight cases in which the impression of a finger or thumb has been repeated after an interval of many years.



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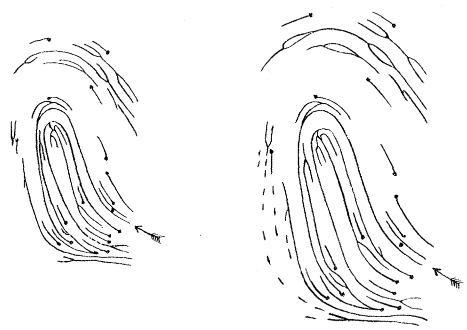

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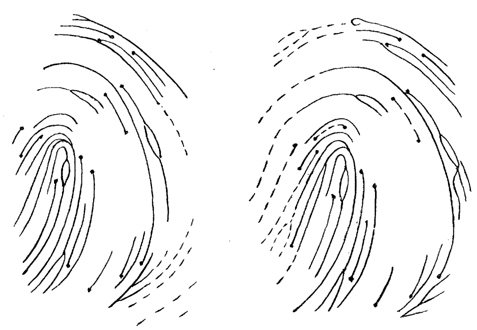

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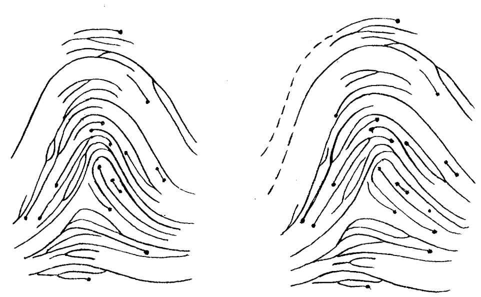

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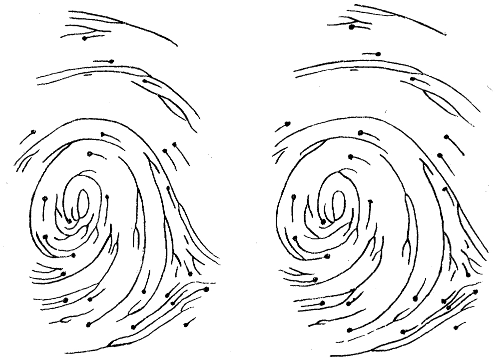
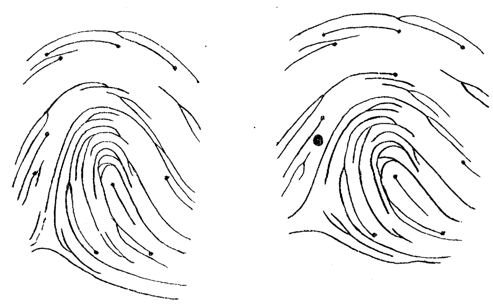
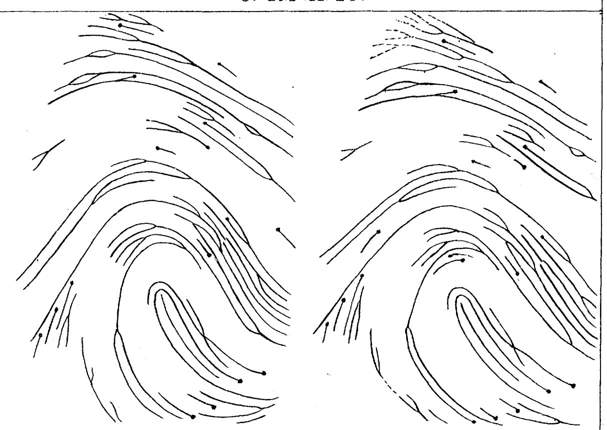


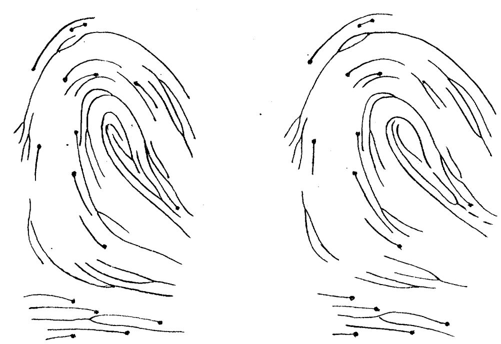
5. F.K.H. 1r.



6. R.F.H. 2r.



7. W.J.H. thumb, r.



8. W.J.H. 3r

West, Newman, lith.

Plate, II. Skeleton maps of the impressions in Plate I, showing the places where ridges begin, through bifurcation or independently.