

as *Mucor racemosus*. The identification was so unmistakable that I utterly fail to understand in what "important features" the fungus differed "from any fungus hitherto described."

In the face of the undoubted fact that the fungus was a characteristic *Mucor*, it seems to me very improbable that it has a genetic relationship with any of the organisms found in the blood, and much more likely that its appearance in the nutrient medium was due to some experimental error.

III. "Method of indexing Finger-Marks." By FRANCIS GALTON, F.R.S. Received April 30, 1891.

Sufficient proof was adduced by me in a memoir read November 27, 1890, before the Royal Society ('Phil. Trans.,' B, 1891), of the extraordinary persistence of the papillary ridges on the inner surface of the hands throughout life. It was shown that the impression in ink upon paper of each finger tip, contained on the average from twenty-five to thirty distinct points of reference, every one of which, with the rarest exception, appeared to be absolutely persistent. Consequently that it was possible to affirm with practical certainty whether or no any two submitted impressions were made by the fingers of the same person.

In the present memoir I shall explain the way in which finger prints may be indexed and referred to after the fashion of a dictionary, and on the same general principle as that devised by A. Bertillon with respect to anthropometric measures, whose ingenious method is now in regular use on a very large scale in the criminal administration of France and elsewhere. I desire to show how vastly the practical efficiency of any such method as that of A. Bertillon admits of being increased by taking finger prints into account in the way about to be described.

It must not, however, be supposed that the use of indexing finger marks is limited to the above purpose, the power of doing so being equally needed for racial and hereditary inquiries. I do not dwell upon these applications now, simply because I am engaged in making them, and the results are not yet ready to be published. I ought, however, to mention that a great increase of experience has fully confirmed my earlier views, that finger marks are singularly appropriate subjects of anthropometric study owing to many distinct reasons. The impressions are easily to be made by anyone who has the proper appliances at hand. They are as durable as any other printed matter, and they occupy very little space. The patterns are usually sharp and clear, and their *minutiae* are independent of age and growth. They are necessarily trustworthy, and no reluctance is shown in per-

mitting them to be taken, which can be founded either upon personal vanity or upon an unwillingness to communicate undesirable family peculiarities.

Without caring to dwell on many of my earlier failures to index the finger prints in a satisfactory way, my description shall be confined to that which has proved to be a success. It is based on a small variety of conspicuous differences of pattern in each of many digits, and not upon the numerous minute peculiarities of a single digit. My conclusions are principally based on a study of the impressions of all ten digits of 289 different persons, but the tables about to be given refer only to the first 100 on my list. These are sufficiently numerous to serve as a fair sample of what we might always expect to find, while they are not too cumbrous to print and to discuss in full detail.

I described in my previous memoir the way in which the impressions had been made that were then shown. A plate of copper was blackened with printer's ink, the ink being of a rather fluid character, and spread very thinly and evenly over its surface by a printer's roller. The thumb, which was then the subject of discussion, was pressed and slightly rolled on the inked plate, and afterwards on the paper. In the present collection of all ten digits, four operations were used in each case. First the four fingers of one hand were simultaneously printed from, and then its thumb in the way above described; afterwards, the other hand was treated in the same way.

Though I have spoken and shall speak only of impressions, it is not really necessary for the purpose of compiling an index to make any impression at all. The entries that are wanted for the index can be derived directly from the fingers themselves.

I rely, for the purpose of indexing, on the three elementary divisions of primaries, whorls, and loops. They are severally expressed by the numerals 1 and 2, 3 and 4, 5 and 6. The reason of this double numeration is that most of the patterns have a definite axis. Those that are formed by ridges which proceed from only one side of the finger, will necessarily lie in a sloping direction across its axis pointing to the one side or the other according to that from which the supply of ridges proceeds. The only patterns that are symmetrically disposed about a vertical axis are *b* and to a lesser degree *a*, *c*, *h*, and *i* in fig. 1. Usually, and, as we may say, normally, the slope of the axis of the pattern is (roughly) parallel to a line drawn from a tip of the forefinger to the base of the little finger. All normal slopes, as well as all the patterns that have no definite axis, are expressed by the odd numerals 1, 3, or 5. All abnormal slopes are expressed by the even numerals 2, 4, or 6. It cannot be too strongly insisted that the words right and left are ambiguous and should not be used here.

FIG. 1.

Elementary divisions	Index number	Symbols of Patterns								Index number
		symmetric.				sloped.				
Primary.	1									1 OR 2
Whorls	3									3 OR 4
Loops.		all sloped.								5 OR 6

The forefingers are the most variable of all the digits in respect to their patterns, their slopes being almost as frequently abnormal as not (see Table II); the third fingers rank next; the little finger ranks last, as its pattern is a loop in nine cases out of ten. I, therefore, found it convenient not to index the fingers in their natural order, but in the way that is shown at the head of the column of figures on the left side of fig. 2. There, the sequence of the numerals that express the

FIG. 2.

L	R	L, R	Left					Right				Index
123, 123	T4, T4	4	3	2	1	T	T	1	2	3	4	
353, 333	35, 35											38.2
353, 333	35, 35											19.2
353, 353	15, 55											6.2
353, 653	35, 35											17.1
355, 353	55, 35											16.1
355, 455	55, 35											49.1
365, 355	55, 55											3.2
415, 555	35, 55											21. a

patterns on the digits, is divided into two groups of three numerals and two groups of two numerals, as 355, 455, 55, 35. The first group 355 refers to the first, second, and third fingers of the left hand; the second group 455 to the first, second, and third fingers of the right hand; the third group 55 to the thumb and fourth finger of the left hand; the fourth group 35 to the thumb and fourth finger of the right hand. The index is arranged in the numerical sequence of these sets of numbers as shown in fig. 2 and in Table I.

Before translating the patterns into numerals, I find it an excellent plan to draw symbolic pictures of the several patterns in the order in which they appear in the impression, or in the fingers themselves, as the case may be, confining myself to the limited number of symbols shown in fig. 1, which have fairly well sufficed for my 289 sets or 2890 finger marks, as well as for many others. A little violence has of course to be used now and then, in fitting some unusual pattern to one of these symbols. But we are familiar with such processes in ordinary spelling, where the same letter does duty for different sounds, as *a* in the words *as*, *ask*, *ale*, and *all*. The merits of this process are many. It facilitates a leisurely revision of first determinations; it affords a pictorial record of the character of each pattern; it prevents mistakes between normal and abnormal slopes; it prevents confusion when changing the sequence of the entries from the order of the impressions to that used in the index; and, lastly, it affords considerable help to a yet further subdivision of the patterns. This may be inferred from the first two lines of fig. 2, which have the same index numbers, but whose pictured forms differ in respect to the two thumbs, and to the middle finger of the left hand.

I will now describe the symbols in detail, and show how such small difficulty as arises from rare transitional or border cases is minimised.

The primaries in their earliest and purest form are sufficiently expressed by the symbol *a*, fig. 1. From this elementary type all other sorts of patterns seem to be lineally descended. A fairly pure form of this type is seen in *b*; this is not infrequent in fingers, but I have not once met with it among some thousands of thumbs. A nascent whorl, still so immature as to count as a primary, is symbolised by *c*; similarly nascent loops, that should undoubtedly be counted as primaries, by *d* and *e*. When, however, the loop form is more pronounced and the pattern has been accepted as a primary only after reasonable hesitation as to whether it was not a loop, a dot is put inside the symbol, as in *f* and *g*, to serve as a warning. In this case, supposing another person to reckon the doubtful finger-mark as a loop and to refer and fail to find it under that head, he would make a second reference by treating it as a primary. A dot always means a possibly transitional case; thus *r* and *s* signify that they had been accepted as loops after some hesitation.

The whorls include circles, ellipses, and spirals, both simple and compound, whatever may be the direction or closeness of their twist. These are so apt to be confounded together unless the impression is from a *rolled* finger and is afterwards scrutinised and outlined (as explained in my previous memoir) that it seems best for the present purpose to group them all, with few exceptions, under the one symbol *h*. The exceptions are these. When two streams of ridges proceed from opposite sides of the finger and interlock, the symbol *i* is used, regardless of all other details. Again, when the whorl is crozier shaped, as in *j* and *k*, it is necessarily enclosed in a loop, but the loop is here ignored. If the crozier approaches very nearly and mistakably to either of the plain eyes *t*, *u*, it is dotted for a warning, as in *l* and *m*.

The loops in their simplest and common forms are shown by *n* and *o*. Frequently they have an internal offset which may be variously feathered or bent, short of being a whorl; all such cases are expressed by *p*, *q*. They have sometimes a conspicuous eye due to an internal curvature of the ridges upon themselves, or even to an eye in the central ridge; these are all expressed by *t* or *u*, in which the surrounding loop is left out in order to avoid multiplicity of lines. When the eye approaches nearly to a crozier as in *l*, *m*, the dotted symbols *r*, *w* are used.

In making a large and complete index, the symbols would, of course, be cast as movable types, and be printed with the letterpress. It will be seen from fig. 2 that there is space for 20 entries in one 8vo page.

I do not expect from my own reiterated experiences that there would be much trouble due to transitional cases, after a standard collection of doubtful forms had been established so as to ensure that different persons should abide by a common rule. I find much uniformity in my own judgment.

I give an index of 100 cases; they are the first that occurred in my catalogue of impressions, which are pasted in two rows on each page, and are consequently numbered 1, 1'; 2, 2', in order; but there are a few blanks, so the numbers in the index happen to run from 1 to 56', with some omissions, and not from 1 to 50'.

These cases afford data for roughly measuring the increase in power of discrimination obtained by basing indexes on the patterns of 1, 2, 3, 6, and 10 digits respectively. It appears from Table III that when all 10 digits are used, the number of different patterns observed in the 100 cases was 83; therefore the average number of references required to pick out a single well-defined case from among these 100 would be equal to 100 divided by 83, that is, to about $1\frac{1}{4}$.

It will also be seen from Table III that, owing to the large effect of correlation, an index based on all the ten digits is not much superior

in efficiency to one that is based on only six, namely, upon the first three fingers of both hands. In the 100 different sets there are 83 varieties of pattern in the one case and 65 in the other, which roughly accords with the relative efficiency of 5 to 4. When all the 289 cases are similarly treated, the relative efficiency comes out as 213 to 139, or roughly as 3 to 2. This is a little better but not much. It is, therefore, a fair question whether it is worth while to impress all the 10 digits. The chief advantage of doing so is to add to the volume of evidence, and to supply data which mutilation, or bad scars, or obliteration due to some exceptional cause might render of value. We also see from Table III that the three fingers of both hands are more than twice as efficient for the purposes of an index as those of one hand only; again, that three fingers are nearly twice as useful as two. I may mention that for my present inquiries into racial and hereditary patterns I am, for various reasons, dealing only with the three first fingers of the right hand, and slightly rolling the forefinger, so as to obtain a full impression of its pattern on the side of the thumb.

The greatest difficulty in constructing a uniformly efficient catalogue lies in the troublesome frequency of plain loops, so that even the method of picture writing fails to analyse satisfactorily the numerous 555, 555; 55, 55 cases. When searching through a large number of similarly indexed prints for a particular specimen, it is a very expeditious method to fix on any one well-marked characteristic of a minute kind, such as an island, or enclosure, or a couple of adjacent bifurcations, that may present itself in any one of the fingers, and in making the search to use a lens or lenses of low power, fixed at the end of an arm, and to confine the attention solely to looking for that one characteristic. The cards on which the finger marks have been made may then be passed successively under the lens with great rapidity. I fear that the method of counting under ridges (as the number of ridges in the AH of my previous memoir) would be difficult to use by persons who were not experts. Anyhow, I have not yet been able to devise a plan for doing so that I can recommend.

Table I.—Numerical

Three first fingers.		Thumb and fourth finger.		Book I.	Three first fingers.		Thumb and fourth finger.		Book I.
Left, 1, 2, 3.	Right, 1, 2, 3.	Left, th., 4.	Right, th., 4.		Left, 1, 2, 3.	Right, 1, 2, 3.	Left, th., 4.	Right, th., 4.	
111	111	15	15	page 52	215	115	55	55	page 48
"	"	51	11	20	"	255	55	55	20'
"	"	55	35	32	253	155	55	55	7'
"	151	51	51	37	255	655	35	35	51
"				46					
115	113	55	55	39	333	155	55	35	14
"	115	15	15	55	"	333	55	33	2
"	"	55	55	4	"	"	55	33	31'
"	155	15	55	34'	"	"	55	35	2'
"	"	55	55	25'	"	"	55	55	36
151	151	54	51	33'	"	353	33	33	45
154	115	55	55	47	"	"	35	35	18
					"	"	35	35	5'
					"	"	53	33	53
155	113	55	55	12	"	"	55	33	4'
"	115	55	55	20a	"	433	33	33	14'
"	116	35	53	1	"	555	35	55	55'
"	155	55	35	6	"	633	35	35	29
"	"	55	55	35'	"	"	"	"	18'
"	"	"	"	45'					
"	553	55	55	35	335	333	53	55	18'
"	555	35	35	23	"	653	55	55	30'
"	"	55	35	50'					
"	"	"	"	10	353	333	35	35	38'
"	"	55	35	54	"	"	15	55	19'
"	633	35	35	56'	"	353	15	55	6'
"	655	55	35	44'	"	653	35	35	17
156	553	35	35	7	355	353	55	35	16
					"	435	55	35	49

Index of 100 cases.

Three first fingers.		Thumb and fourth finger.		Book I.	Three first fingers.		Thumb and fourth finger.		Book I.
Left, 1, 2, 3.	Right, 1, 2, 3.	Left, th., 4.	Right, th., 4.		Left, 1, 2, 3.	Right, 1, 2, 3.	Left, th., 4.	Right, th., 4.	
365	355	55	55	page 3'	555	555	55	55	page 19
415	555	35	55	21a	"	"	"	"	3
433	433	35	35	10'	"	"	"	"	40'
453	355	55	55	32'	565	155	55	35	22
455	355	55	55	11	633	655	35	35	5
"	455	35	35	56	635	653	55	55	29'
"	"	"	"	41'	653	153	55	55	1'
515	153	55	55	23'	"	653	35	33	28'
"	166	55	35	49'	655	155	55	35	36'
553	153	15	15	37'	"	"	55	55	15'
"	333	55	35	13	"	"	55	55	12'
"	353	55	55	22'	"	335	55	55	21a'
"	553	55	35	27'	"	455	35	55	53'
"	"	"	"	16'	"	553	35	35	20a'
"	"	55	55	24	"	555	35	55	47'
					"	"	55	55	44
					"	"	"	"	52'
555	115	55	55	40	"	653	35	33	26'
"	151	55	35	27	"	"	35	55	21'
"	153	55	53	23	"	655	55	35	25
"	253	35	35	26	"	"	55	55	51'
"	513	55	55	28	"	"	"	"	21
"	553	55	55	39'	"	"	"	"	30
"	555	55	55	15	"	"	"	"	
"	"	"	"	41	665	655	55	55	46'
"	"	"	"	17'	"	"	"	"	

Table II.—Analysis of the 100 Cases in Table I.

Forefinger of left hand.		
Pattern.	Distinguishing number of pattern.	Number of cases.
Primary, plain.....	1	26
" nascent loop, slope normal ...		
" " " slope abnormal ...	2	4
Whorl, plain	3	23
" with tail, slope normal.....		
" " slope abnormal.....	4	6
Loop, slope normal.....	5	21
" slope abnormal	6	20
Total cases.....	..	100

Table III.—Further Analysis of the 100 Cases in Table I.

Number of times in which each pattern occurs.	Set of digits observed.							
	First 2 fingers of left hand.		First 3 fingers of left hand.		First 3 fingers of both hands.		All the digits of both hands.	
	Number of		Number of		Number of		Number of	
	Pat-terns.	Cases.	Pat-terns.	Cases.	Pat-terns.	Cases.	Pat-terns.	Cases.
1	5	5	13	13	49	49	71	71
2	4	8	5	10	6	12	10	20
3	—	—	1	3	4	12	1	3
4	1	4	1	4	4	16	—	—
5	—	—	2	10	1	5	—	—
6	1	6	1	6	1	6	1	6
—	—	—	—	—	—	—	—	—
10	1	10	—	—	—	—	—	—
11	—	—	—	—	—	—	—	—
12	—	—	1	12	—	—	—	—
13	—	—	1	13	—	—	—	—
14	—	—	1	14	—	—	—	—
15	—	—	1	15	—	—	—	—
16	2	32	—	—	—	—	—	—
17	1	17	—	—	—	—	—	—
18	1	18	—	—	—	—	—	—
Total cases	..	100	..	100	..	100	..	100
Number of different patterns	16	..	27	..	65	..	83	..

IV. "On the Anatomy and Physiology of *Protopterus annectens*." By W. N. PARKER, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff. Communicated by W. H. FLOWER, F.R.S. Received May 4, 1891.

(Abstract.)

The work which has resulted in the present paper was begun in Freiburg in the summer of 1888, when the author was fortunate enough, owing to the generosity of Professor Wiedersheim, to obtain a number of fresh specimens for examination. As so many interesting points presented themselves at an early stage in the research, a short preliminary notice, without illustrations, was published in the following autumn ('Berichte d. Naturforsch. Gesellschaft zu Freiburg i.Br.,' vol. 4, 1888).*

This notice merely forms the basis of the present paper, in which the whole subject has been worked out in greater detail. A number of new facts are recorded, some of the author's earlier conclusions modified, and the paper illustrated with 11 plates containing 71 figures.

With the exception of certain special details, the structure of the skeleton and of the nervous and muscular systems is not described, the paper consisting mainly of an account of other organs which have not received so much attention from previous observers, and of a comparison of *Protopterus* with the other genera of Dipnoi, so far as their structure is known, as well as with other Ichthyopsida.

The author returns his sincere thanks to the Council of the Royal Society for the grant out of which various expenses connected with the investigation were defrayed, as well as to Professor Wiedersheim, not only for the gift of abundant fresh and preserved material, but also for his continued help and advice during the progress of the work. To Professor Howes the author is indebted for many valuable suggestions.

A number of details with regard to the habits of *Protopterus* in captivity are given, and reference is made to Stuhlmann's observations with regard to its mode of life under natural conditions.

The paired extremities, the movements of which are more like those of limbs than of fins, show no connexion with the cheiropterygium, and, in spite of their considerable nerve supply, are evidently greatly degenerated structures as regards their free portions. Sensory organs are not present on them, and they therefore cannot have a tactile function. Their distal ends, like the apex of the tail, are very variable, and can undoubtedly be reproduced when lost by

* See also 'Nature,' vol. 39, p. 19.