Perspectives

Anecdotal, Historical and Critical Commentaries on Genetics

Edited by James F. Crow and William F. Dove

GALTON and Identification by Fingerprints

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THE history of true fingerprints, or as they are sometimes redundantly referred to, dermal fingerprints, gives an interesting background to current discussion of the use of DNA "fingerprints" as a tool for forensic identification. History may not repeat itself; it may only, as Mark Twain said, rhyme, but some of the issues that have arisen in consideration of the forensic use of DNA have striking parallels a century ago.

Fingerprints as a device for personal identification were not widely used before they were introduced in a district in India in the 1870s by Sir WILLIAM HERSCHEL, grandson of the astronomer of the same name. In 1880, HERSCHEL and, independently, HENRY FAULDS brought them to public attention in England as a potential method for identifying criminals, but it was only in 1890–95 with the work of FRANCIS GALTON (CROW 1993) that the use of fingerprints acquired a scientific basis.

In his 1892 book *Finger Prints* and in two subsequent books (1893, 1895), GALTON identified and studied the basic issues that must be addressed in order that fingerprints be an efficient and reliable method of criminal identification. An individual fingerprint is a marvelously complex pattern. Someone who has not looked closely at a fingerprint might suppose that identification would be accomplished by a subjective evaluation of the gross pattern, for example, the type (arch, loop, or whorl) together with an almost artistic sensitivity to notions of shape. But while these gross features were indeed useful for rough classification, GALTON stressed that identification was accomplished precisely only through attention to the *minutia* of the prints—tiny islets and forks in the ridges (Figure 1).

The basic issues GALTON addressed in his study of fingerprints are also important with "DNA fingerprints," but two of them are not matters of current dispute:

An individual's prints must be persistent over time. From examples furnished by HERSCHEL and others he gathered himself, GALTON was able to establish that human fingerprints were remarkably stable from early youth to advanced age, even to after death. They changed size with growth, but (with one small exception) they did not change in their minutia. The single exception of several hundred features studied was a minute feature in one boy's print, a slight gap between two ridges that closed between ages $2^1/_2$ and 15.

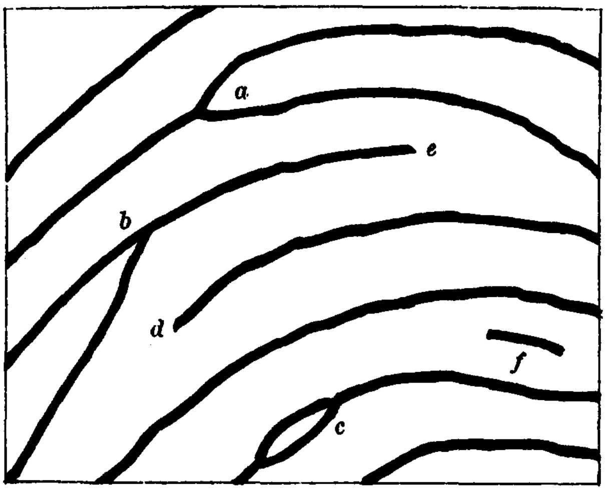
A scheme for classification must be devised that permits efficient filing and retrieval of prints. GALTON devised taxonomic methods starting with a set of basic patterns, a method that permitted pigeonhole storage in a way that survived to the computer age.

However, two other issues GALTON raised and dealt with are at the center of current discussions:

The question, were fingerprints unique or at least sufficiently distinguishable to be used for evidence, had to be addressed convincingly. GALTON invented an ingenious probability argument to argue for near-uniqueness.

The heritability of fingerprints and their relationship within families and among ethnic or racial groups needed study. GALTON found, from sib and twin studies, that fingerprints were heritable, but not to a degree that would preclude identification, and he found only small racial differences.

GALTON's assessment of the probability of a match: GALTON took as his goal to attempt "to appraise the evidential value of finger prints by the common laws of Probability, paying great heed not to treat variations that are really correlated, as if they were independent" (1892, p. 10). In order to break a single fingerprint into components, he posed the question: if a small square were dropped onto a fingerprint at random, hiding all the portion of the pattern that lay beneath the square, and an experienced analyst attempted to reconstruct by guesswork the hidden portion based on what was observed outside the small square, how large should the square be for the probability of a successful guess to be $^1/_2$? From experiment he found that a square with a side about the width of six ridges would do the trick—actually, from 75 trials GALTON estimated that the average chance of a successful guess with a six-ridge square would be about $^1/_3$. He believed that a five-ridge square would be nearer to the size sought, but he took the six-ridge square in order to err "on the safe side."



Characteristic peculiarities in Ridges

FIGURE 1.—GALTON's illustration of the characteristic peculiarities in fingerprint ridges, showing the principal types of minutia (from his *Finger Prints,* 1892, Plate 3).

A full fingerprint consisted of 24 six-ridge squares, and GALTON then claimed, "These six-ridge-interval squares may thus be regarded as independent units, each of which is equally liable to fall into one or other of two alternative classes, when the surrounding conditions are alone known" (1892, p. 109). Thus, given that each square was guessed with full knowledge of the surrounding territory, he calculated the chance of a successful composite guess at $1/2^{24}$, a value he regarded as an overestimate. In words that pre-echo those of many who have applied probability in assessing the force of DNA evidence, he wrote, "It is hateful to blunder in calculations of adverse chances, by overlooking correlations between variables, and to falsely assume them independent, with the result that inflated estimates are made which require to be proportionately reduced. Here, however, there seems to be little room for such an error" (1892, p. 109).

GALTON completed his calculation by assessing the chances that he would guess the correct conditions for reconstructing each square. He took as $1/2^4$ the chance that he would have guessed correctly "the general course of the ridges adjacent to each square," and he estimated the chance that he would have correctly guessed the numbers of ridges entering and leaving each square as $1/2^8$. Both numbers were taken as gross overestimates. This gave him an overall assessment of the chance that a random fingerprint would match a specified one as $1/2^{24} \times 1/2^8 \times 1/2^4 = 1/2^{36}$, "or 1 to about sixty-four thousand millions. The inference is, that as the number of the human race is reckoned at about sixteen thousand millions, it is a smaller chance than 1 to 4 that the print of a *single* finger of any given person would be exactly like that of the same finger of any other member of the human race" (1892, pp. 110–111). (In testimony in 1893, reprinted in GALTON 1895, p. 35, he corrected his figure for the population to 1.6 billion, which would give odds of 1 to 39. GALTON characterized the chance of two individuals' fingerprints not being identical as "enormously greater than what in popular language begins to rank as certainty.")

To be accepted today, GALTON's modeling would require more detail, but with minor qualifications (and acceptance of GALTON's personal experience with fingerprint patterns as an adequate basis upon which to form estimates) it can be rigorously defended as correct and conservative. He also computed the allowance that should be made if two prints should match in all but one, two, or more of 35 minutiae. If prints of two or three fingers were available, GALTON would square or cube his probability, assuming the developmental equivalent of linkage equilibrium. He concluded, "Whatever reductions a legitimate criticism may make in the numerical results . . . , the broad fact remains, that a complete or nearly complete accordance between two prints of a single finger, and vastly more so between the prints of two or more fingers, affords evidence requiring no corroboration, that the persons from whom they were made are the same" (1892, pp. 112–113).

GALTON's study of the heritability of fingerprints and of racial differences: GALTON's interest in fingerprints had initially been aroused in connection with his studies of heredity, and he investigated these topics in the later chapters of his 1892 book. He focused here on the gross patterns of the prints, since he had found that even the closest relatives could be distinguished on the basis of the minutiae of their fingerprints. Indeed, present research shows that even monozygotic twins are not identical in fingerprints.

GALTON started with the association in gross pattern in sib pairs, using the simplest classification into arches, loops, and whorls. His goal was in close parallel to current studies that test for Hardy-Weinberg equilibrium by testing for excess homozygosity in tables of counts of alleles. GALTON formed a table of counts from 105 sib pairs (Figure 2), giving particular attention to the diagonal entries. But how to evaluate this table? How to decide whether the diagonal elements are too large? His solution was a nice precursor to the chi-squared test, which KARL PEARSON would introduce only eight years later. How, GALTON asked, would the counts be arrayed if the individuals classified were independent? He explained how to form such a table by dividing the product of marginal totals by the grand total, so that the expected number of Arch-Arch pairs among 105 with these marginal totals would be $(19 \times 10)/105$. He noted that all three of the diagonal counts exceeded these "random" expectations, even though they fell far short of the maximum counts achievable with these marginal totals, namely 10, 61, and 25. He repeated this study with 150 fraternities and a much finer classification of 53 gross patterns. The results were essentially the same: the total of the observed diagonal counts was

TABLE XXII.

Observed Fraternal Couplets.

B children.	A children. Arches.	A children. Loops.	A children. Whorls.	Totals in B children.
Arches . . .	5	12	2	*19*
Loops . . .	4	42	15	*61*
Whorls . . .	1	14	10	*25*
Totals in A children	*10*	*68*	*27*	105

FIGURE 2.—A reconstruction of GALTON's table describing sib couplets (GALTON 1892, p. 175).

larger than under a "random" hypothesis, but far short of the greatest possible number. He gave as a measure of fraternal resemblance the relative position of the observed count on a centesimal scale, measuring as parts of 100° the distance of the observation on a scale between the "Random" (0°) and the "Utmost feasible" (100°). In his examples, his measures tended to fall between 10° and 20°, values he interpreted as affirmative evidence that there was a "decided tendency to hereditary transmission" (1892, p. 189).

GALTON found even closer similarities in 17 sets of twins. He did not differentiate between monozygotic and dizygotic twins, but in none of 17 sets of twins did he find near identity in the minutiae, although PEARSON (1930, Plate XVIII) reproduced a set of prints from GALTON's collection of twins that show remarkable similarity in pattern. GALTON also examined the relative contributions of the parents, and he thought he detected a slight tendency for the maternal influence on pattern to exceed the paternal, although the uncertainty in the figures (the effect was present for only the middle finger of the three he studied) led him "to reserve an opinion as to their trustworthiness" (1892, pp. 190–191). If valid, this would be a curious example of imprinting.

GALTON expected to find racial differences in fingerprint patterns, but when he investigated this, he was surprised at the result. He used data gathered from children in schools in London, Cardiff, and Niger, with the willing—even eager—assistance of the headmasters. He found (Figure 3) slight "statistical" differences, but concluded nonetheless that "it may emphatically be said that there is no *peculiar* pattern which characterises persons of the above races" (1892, pp. 192–193).

TABLE XXX.

Frequency of Arches in the Right Fore-Finger.

No. of Persons.	Race.	No. of Arches.	Per Cents.
250	English	34	13·6
250	Welsh	26	10·8
1332	Hebrew	105	7·9
250	Negro	27	11·3
	Hebrews in detail—		
500	Boys, Bell Lane School . .	35	7·0
400	Girls, Bell Lane School . .	34	8·5
220	Boys, Tavistock St. & Hanway St.	18	8·2
212	Girls, Hanway Street School .	18	8·5

FIGURE 3.—A reconstruction of GALTON's table describing frequencies of arches (GALTON 1892, p. 194).

The acceptance of fingerprints as evidence: GALTON's analysis is at least superficially similar to current assessments of the probability of a match with DNA profiles—a profile is broken down into components, and probabilities for the components are estimated and cautiously multiplied, at all stages erring on the side of over-estimation to ensure a safe margin. But whether this analysis had any impact upon the adoption and general acceptance of fingerprints as evidence is another matter. The first, and for many years the standard, text on the application of fingerprints was E. R. HENRY's *Classification and Uses of Finger Prints* (1900). HENRY included a brief probability calculation of his own. But it was far less satisfactory than GALTON's, and HENRY put more weight on a few striking court cases where fingerprints had been used with dramatic success than he did on theory. HENRY did allow that "It may happen that circumstantial evidence of apparently overwhelming completeness will sometimes lead to a mistaken judgment, but every Court has to act upon probabilities, for if certain evidence, in the strict meaning of the words, were required, no punishments could be inflicted" (p. 58). Other texts and documents took the effective uniqueness for granted. SCOTLAND YARD (1904) did admit to the need to guard against laboratory error, though: "One or two instances having come to notice in which the names of the wrong prisoner had inadvertently been recorded on the slips sent for record, it became necessary to provide an effective check against this source of error" (pp. 10–11).

HENRY's discussion, including at least some probability-based argument for the force of fingerprint evidence, persisted at least through his 7th edition (1934), but in other texts the uniqueness of fingerprints was simply taken for granted. For example, in J. A. LARSON's *Single Fingerprint System* (1924), we find "No two fingerprints are identical in pattern" (p. 2), and WALTER R. SCOTT (1951, p. 9) wrote in a handbook, "A normal person has ten fingers, each finger has its own individual and distinctive ridge pattern or trademark. No two are alike." The F.B.I. handbooks of the 1930s sometimes helpfully provided citations to court cases where fingerprints were admitted as definitive proof of identity, but offered no argument for uniqueness, being content to describe them as "a certain and quick means of identification" (HOOVER 1939, p. 1). The claim was generally presented with no more support than MARK TWAIN had given in *Life on the Mississippi* (1883, p. 345): "When I was a youth, I knew an old Frenchman who had been a prison-keeper for thirty years, and he told me that there was one thing about a person which never changed, from the cradle to the grave—the lines in the ball of the thumb; and he said that those lines were never exactly alike in the thumbs of any two human beings."

Fingerprints were occasionally challenged, as in *Finger-Prints Can Be Forged*, by A. WEHDE and J. N. BEFFEL (1924), but even then the challenge was based on the allegation that prints could be "lifted" and transferred, not that they were unreliable as tools for identification.

How did fingerprints come to be so universally accepted? GALTON's calculation of 1 chance in 64 billion was quoted ceremonially in the decades following his book, but it seems fair to say that by the late 1920s the basis for their acceptance was neither scientific argument nor well-documented empirical study. Rather, a plausible surmise is that it was (i) the striking visual appearance of fingerprints in the court, (ii) a few dramatically successful cases, and (iii) a long period in which they were used without a single case being noted where two different individuals exhibited the same pattern. It seems equally plausible that, while the acceptance of DNA evidence may be hastened by scientific argument, it will cease to be a contentious issue only after a similarly long record accumulates of successful use without notable contradiction.

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