The Individualization Fallacy in Forensic Science Evidence

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I. FOREWORD: THE TWO STEPS IN FORENSIC IDENTIFICATION

Forensic identification science involves two fundamental steps. The first step is to compare a questioned item of evidence to an exemplar from a known source and judge whether they appear so alike that they can be said to match. The second step is to assess the meaning of that reported match: What is the probability that the questioned and the known originated from the same source?[1]

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1. From an evidentiary value perspective, the two steps that we identify might be referred to as "reliability" and "diagnosticity," respectively. *See generally* DAVID A. SCHUM, EVIDENTIAL FOUNDATIONS OF PROBABILISTIC REASONING (1994). The first step involves the reliability of the evidence because it concerns the value of the expert's testimony for establishing that the questioned and the known samples do, in fact, share characteristics. The second step involves the diagnosticity of the evidence because it concerns the value of the match conclusion for drawing an inference that the questioned and known samples share a common source.

Different risks of error are present at each step. The risk of error in the first step is that a reported match between a questioned and a known sample might not really match. Even if the method used to compare questioned and known samples were flawless, an error could occur if, for example, one of the samples had been mislabeled or mixed up with a different sample. The risk of error associated with the second step is that, while accurate, the reported match may have arisen through coincidence and not because the samples share a common source. The risks of error at both steps affect the ultimate inferences that can be drawn about the identification evidence in a case.[2]

Both risks are subjects of far too little research. As to the first step, existing standards and procedures do not provide sufficient protection from erroneous conclusions that two marks are indistinguishably alike—that is, that they "match" when in fact they differ. Few, if any, criminalistics subfields have objective standards for deciding whether two patterns match. That determination is left to the judgment of each examiner. For example, consider David Stoney's discussion of fingerprint examination standards:

> How much correspondence between two fingerprints is sufficient to conclude that they [are the same pattern] . . . ? An adequate answer . . . is not currently available. The best answer at present . . . is that this is up to the individual expert fingerprint examiner to determine, based on that examiner's training, skill, and experience. Thus, we have an ill-defined, flexible, and explicitly subjective criterion for establishing fingerprint identification . . . . Any unbiased, intelligent assessment of fingerprint identification practices today reveals that there are, in reality, no standards.[3]

The lack of objective standards helps explain the disturbing findings from the small body of research that has been conducted on pattern matching by forensic scientists. In some tests, examiners disagreed with one another about whether various images matched.[4] In others, examiners who agreed that two patterns matched disagreed

2. *See* Jonathan J. Koehler et al., *The Random Match Probability (RMP) in DNA Evidence: Irrelevant and Prejudicial?*, 35 JURIMETRICS J. 201, 215-16 (1995) (arguing that the inferential limits of a reported match depend more on the risk of error at the first step when the risk of a coincidental match is very low).

3. David A. Stoney, *Measurement of Fingerprint Individuality*, *in* ADVANCES IN FINGERPRINT TECHNOLOGY 327, 329 (Henry C. Lee & Robert E. Gaensslen eds., 2d ed. 2001).

4. *See, e.g.*, Jodi Sita et al., *Forensic Handwriting Examiners' Expertise for Signature Comparison*, 47 J. FORENSIC SCI. 1117, 1119 (2002) (finding incorrect opinions even among experienced handwriting analysts); John I. Thornton & Joseph L. Peterson, *The General Assumptions and Rationale of Forensic Identification*, *in* 4 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY 1, 9 (David L. Faigman et al. eds., 2006-2007 ed. 2006); Collaborative Testing Service, Forensic Testing Program, http://www.collaborativetesting.com/forensics/report_list.html (various fields, various years).

(sometimes dramatically) on what constituted the match.[5] Examiners differ not only in their ability to perceive pattern similarity, but also in their thresholds for declaring matches.[6]

Other research suggests that the match judgments of experienced criminalists are influenced by extraneous information. A study by Itel Dror et al. found that four of five fingerprint experts who previously had identified two prints as a match reached different conclusions on a later examination, after they learned that the prints were from different persons.[7] In a follow-up study, six other fingerprint experts were provided with eight pairs of prints that they previously had judged.[8] The study found that introduction of contextual information induced four of the six experts to change at least one of their previous match judgments. Some pairs that were judged to be exclusions subsequently were judged to be matches, and vice-versa. Surprisingly, some experts made inconsistent decisions in the control condition where contextual information was not introduced (thus reflecting random, and not systematic, error). These results suggest that criminalists should employ the same kind of blind examination procedures that are used widely in other fields.[9] Such

5. I.W. Evett & R.L. Williams, *A Review of the Sixteen Points Fingerprint Standard in England and Wales*, 46 J. FORENSIC IDENTIFICATION 49, 59 (1996) (finding that although examiners agreed that two fingerprints matched, for one pair of prints some examiners believed they saw as few as ten points of agreement and others as many as forty; for another pair of prints some examiners saw as few as fourteen points of agreement and others as many as fifty-six; and so on).

6. Victoria Phillips et al., *The Application of Signal Detection Theory to Decision-Making in Forensic Science*, 46 J. FORENSIC SCI. 294, 300-01 (2001).

7. Itiel E. Dror et al., *Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications*, 156 FORENSIC SCI. INT'L 74, 76 (2006).

8. Itiel E. Dror & David Charlton, *Why Experts Make Errors*, 56 J. FORENSIC IDENTIFICATION 600, 610 (2006).

9. D. Michael Risinger et al., *The* Daubert/Kumho *Implications of Observer Effects in Forensic Science: Hidden Problems of Expectation and Suggestion*, 90 CAL. L. REV. 1, 45-46 (2002). The phrase "blind examination procedures" can have more than one meaning. Here, we use the term to refer to blindness or lack of knowledge about facts of the target case or the beliefs of other investigative or prosecutorial personnel. Such contextual blindness helps ensure that analysts base their conclusions on the forensic science evidence alone. Blind examination can also refer to a testing situation in which the analysts who are asked to determine whether two or more specimens, prints, markings, etc. match are unaware that they are being tested. Across various forensic fields, the data indicate that analysts' performance improves when the analysts know that they are being tested. Joseph L. Peterson et al., *The Feasibility of External Blind DNA Proficiency Testing. I. Background and Findings*, 48 J. FORENSIC SCI. 21, 26-27 (2003). Presumably, analysts behave more vigilantly when they know there are being evaluated. This is why we and many others believe that casework accuracy rates in the forensic sciences would be more accurate if measured by performance on proficiency tests in which examiners do not know they are being tested. Michael J. Saks & Jonathan J. Koehler, *The Coming Paradigm Shift in Forensic Identification Science*, 309 SCIENCE 892, 893-94 (2005).

procedures would protect first-stage judgments from the contextual influences that contribute to errors.[10]

As Itiel Dror and David Charlton point out, "How rare and under what conditions errors occur at a practical level is still unclear at this stage."[11] One reason for this knowledge gap is the dearth of high quality proficiency tests across the various disciplines. Such tests should be closed (i.e., the analyst is blind to the fact that the test materials are not part of ordinary case work), be external (i.e., administered by a disinterested party), and use realistic case samples. Unfortunately, proficiency tests that include all three ingredients are virtually nonexistent. On one hand, results from the proficiency tests that have been conducted sometimes reveal disturbingly high error rates. On the other hand, performance on proficiency tests likely overestimates performance in actual casework because the tests are open, tend to be relatively easy, and lack the biasing contextual information that is available in much real casework.[12] Although forensic science leaders, on occasion, have declared errors to be so frequent as to be "unacceptable,"[13] the fact that errors occur with some regularity signals that a reported match between a pair of markings probably has less probative value than examiners claim or than judges and juries assume.

Popular television programs such as *CSI*[14] and *Forensic Files*[15] reinforce the notion of individualization in the collective public imagination by offering confident pronouncements from scientists about whose hair was recovered from the knife or which gun fired the murderous bullet. But can forensic science really make such exact determinations? Can forensic scientists be sure that a particular hammer, to the exclusion of all other hammers in the world, produced the imprints observed on a victim's body? The concept of individualization, which lies at the core of numerous forensic science subfields, exists only in a metaphysical or rhetorical sense. There is no scientific basis for the individualization claims in forensic sciences.

Part II of this Essay explains what we mean by the term "individualization fallacy" and describes the origins of individualization in criminalistics. Part III critically examines the arguments offered in support of the individualization hypothesis. This

10. Robert B. Stacey, *Report on the Erroneous Fingerprint Individualization in the Madrid Train Bombing Case*, 54 J. FORENSIC IDENTIFICATION 706, 715 (2004).

11. Dror & Charlton, *supra* note 8, at 614.

12. Saks & Koehler, *supra* note 9, at 895.

13. David L. Grieve, *Possession of Truth*, 46 J. FORENSIC IDENTIFICATION 521, 524 (1996).

14. *CSI: Crime Scene Investigation* (NBC television broadcast 2000-present).

15. *Forensic Files* (Court TV television broadcast 2000-present).

Part also addresses the second step in forensic identification: What inferences can be drawn from a forensic scientist's conclusion that an exemplar (such as a partial fingerprint, handwriting sample, or tireprint) matches a known source? Forensic scientists across a broad array of sub-specialties long have maintained that such a finding is synonymous with a conclusion that the exemplar marking is produced by the known source. Part IV gives a historical account of scientists who have recognized the problem of individualization in forensic science. Part V offers suggestions for ways to improve the scientific foundation of identification in criminalistics. Finally, Part VI concludes that forensic scientists must provide sound evidence for their conclusions and should avoid exaggerating their results.

II. THE INDIVIDUALIZATION FALLACY

In his recent book on DNA typing, David Balding explains what he terms "the uniqueness fallacy."[16] Attorneys, judges, and experts commit this fallacy in cases involving DNA evidence when they assume that a set of genetic markers that is expected to occur less than once per five billion people (a denominator that roughly equals the earth's population) must be unique. An illustration is provided by the following argument offered in the O.J. Simpson murder trial:

> [L]adies and gentlemen, his blood on the rear gate with that match, that makes him one in 57 billion people that could have left that blood, I mean there is [sic] what, five million [sic] people on the planet, that means you would have to go through 57 billion people to find the DNA profile that matches Mr. Simpson's. There is [sic] only five billion people on the planet. Ladies and gentlemen, that is an identification, okay, that proves it is his blood. Nobody else's on the planet; no one.[17]

Balding refers to a British case in which the appellate judge made a similar assumption: "I should think there are not more than 27 million males in the United Kingdom, which means that it is unique."[18] Likewise, a forensic science textbook states: "Balthazard has mathematically determined that the probability of two individuals having the same fingerprints is one out of 1×10^{60} . . . . This probability is so small as to exclude the possibility of any two individuals having the same fingerprints."[19] In yet another example of

16. DAVID J. BALDING, WEIGHT-OF-EVIDENCE FOR FORENSIC DNA PROFILES 148 (2005).

17. Transcript of Closing Argument by Ms. Clark at *21, People v. Simpson, No. BA097211, 1994 WL 737964 (Cal. Super. Ct. Dec. 15, 1994), 1995 WL 672671.

18. R v. Doheny, [1997] 1 Crim. App. 369, 384 (1996).

19. RICHARD SAFERSTEIN, CRIMINALISTICS: AN INTRODUCTION TO FORENSIC SCIENCE 73 (9th ed. 2007).

the same faulty logic, Keith Inman and Nora Rudin argue that objects of forensic interest are unique by analogy to the asserted uniqueness of snowflakes, claiming that the number of ways that water molecules can be arranged into a typical snowflake:

> is so astronomically larger than the number of snowflakes that have ever existed that it is unreasonable to believe that any one arrangement has occurred more that [sic] once. When a characteristic (or characteristics) of an item can be described in such a fashion, it is believed to be unique, with no duplicate on earth. It has then been individualized.[20]

Although markers that rarely occur *might* be unique, it is a fallacy to infer uniqueness from profile frequencies simply because they are smaller than the number of available objects. A simple analogy clarifies this point: Imagine a machine that prints lottery tickets with numbers 00 through 99. This machine can print one hundred different tickets. Suppose that each of ten customers purchases one ticket and that the machine generates ticket numbers at random, with replacement. The total number of unique tickets that could be sold (one hundred) exceeds the population of customers (ten) by a factor of ten. And yet there is no law of mathematics or nature that prevents two (or more) customers from being issued different tickets bearing the same number. Indeed, the probability of that happening is nearly 40%.[21]

Some people might be surprised by the rather high chance of finding matching lottery tickets in this example. Empirical research demonstrates that people commit an array of errors when describing and interpreting probabilistic evidence like DNA random match probabilities.[22] Probabilistic reasoning is hard, and assigning an appropriate weight to unfamiliar and extreme probabilistic events,

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20. KEITH INMAN & NORA RUDIN, AN INTRODUCTION TO FORENSIC DNA ANALYSIS 4 (1st ed. 1997).

21. The probability of at least two people sharing a winning lottery ticket in our example is

$$1 - \left(\frac{100 \times 99 \times 98 \times \ldots \times 91}{100^{10}} \right) = 37.2\% .$$

This computation is similar to that used to solve the famous "birthday problem," in which the probability that two people in a small gathering would have the same birth date is found to be far greater than human intuition would suggest. *See* Persi Diaconis & Frederick Mosteller, *Methods For Studying Coincidences*, 84 J. AM. STAT. ASS'N 853, 857 (1989).

22. *See, e.g.*, David H. Kaye et al., *Statistics in the Jury Box: How Jurors Respond to Mitochondrial DNA Match Probabilities*, J. EMPIRICAL LEG. STUD. (forthcoming), *available at* http://ssrn.com/abstract=996134; Jonathan J. Koehler, *Error and Exaggeration in the Presentation of DNA Evidence*, 34 JURIMETRICS J. 21 (1993); Jonathan J. Koehler & Laura Macchi, *Thinking About Low-Probability Events: An Exemplar Cuing Theory*, 15 PSYCHOL. SCI. 540 (2004).

such as those that occur 0.1% or 0.001% of the time, is particularly challenging. Certainly, a criminalist's work and a fact-finder's task would be simplified if they could assume that physical evidence reportedly matching a potential source resulted in unique and absolute identification of the source of the evidence. Unfortunately, that is not possible on current knowledge. This is the central point of this Essay. The concept of "individualization," which lies at the core of numerous forensic science subfields, exists only in a metaphysical or rhetorical sense. It has no scientific validity, and it is sustained largely by the faulty logic that equates infrequency with uniqueness. We next discuss the implications of this fallacy and offer suggestions for how the science and practice of criminalistics might proceed in its absence.

A. Reliance on the Notion of Individualization

The "individualization fallacy," as we term it, is a more fundamental and more pervasive cousin of Balding's uniqueness fallacy. Criminalists seek to individualize crime scene evidence to its unique source and frequently claim to have achieved individualization in specific instances. Individualization has been defined as "[t]he process of placing an object in a unit category that consists of a single unit. Individualization implies uniqueness."[23] Individualization refers to "absolute specificity and absolute identification."[24] Though occasionally criminalists are more conservative, for nearly a century they clearly and repeatedly have characterized individualization as fundamental to what they do. "Criminalistics is the science of individualization."[25] "Individualization is unique to forensic science."[26] "The concept of individualization is clearly central to the consideration of physical evidence. . . . Our belief that uniqueness is both attainable and existent is central to our work as forensic scientists."[27] A forensic science textbook states:

> The major members of the pattern group are fingerprints, questioned documents, tool mark, and firearms evidence, and other patterns, such as footwear and tire impressions. This kind of evidence consists of patterns that might be called individualization

23. Thornton & Peterson, *supra* note 4, at 11.

24. David A. Stoney, *What Made Us Ever Think We Could Individualize Using Statistics?*, 31 J. FORENSIC SCI. SOC'Y 197, 197 (1991).

25. James W. Osterburg, *The Evaluation of Physical Evidence in Criminalistics: Subjective or Objective Process?*, 60 J. CRIM. L. & CRIMINOLOGY 97, 97 (1969).

26. PETER R. DE FOREST ET AL., FORENSIC SCIENCE: AN INTRODUCTION TO CRIMINALISTICS 7 (1983).

27. KEITH INMAN & NORAH RUDIN, PRINCIPLES AND PRACTICE OF CRIMINALISTICS: THE PROFESSION OF FORENSIC SCIENCE 45, 123 (2001).

> patterns. Under favorable circumstances, individualization-pattern evidence can be attributed to a unique source.[28]

To practicing forensic scientists, individualization is more than an abstraction or an idealization; it is the state of their art. For example, a firearms examiner testifying in a federal court claimed to be able to identify the unknown weapon "to the exclusion of every other firearm in the world."[29] Similar claims are made by examiners of other kinds of toolmarks,[30] as well as of fingerprints,[31] bitemarks,[32] handwriting,[33] shoeprints,[34] tiremarks,[35] and other objects of forensic interest. Even practitioners from areas where the inability to individuate is recognized might offer testimony that borders on individualization. For example, a microscopic hair comparison expert testified that when questioned and known hairs are consistent, "the [questioned] hairs either did originate from that [known] source, or there could be or might be another individual in the world somewhere that might have the same microscopic characteristics."[36]

Elsewhere, we have used the phrase "discernible uniqueness" to capture the presumption of criminalists who object that uniqueness is not merely a hypothetical construct, but a conclusion that is frequently attainable in practice.[37] The assumption of discernible uniqueness endows criminalistics with important practical benefits. It enables criminalists to assert definitive conclusions in casework. At the same time, it relieves criminalistics of the rigors of developing measures of object attributes and collecting population data on the frequencies of variations in those attributes. It also exempts the various subfields from determining the proper statistical model for estimating random match probabilities, calculating those probabilities in actual cases, and explaining to judges and juries the extent to

28. Robert E. Gaensslen & Kimberly R. Young, *Fingerprints*, *in* FORENSIC SCIENCE: AN INTRODUCTION TO SCIENTIFIC AND INVESTIGATIVE TECHNIQUES 341 (Stuart H. James & Jon J. Nordby eds., 2d ed. 2005) (emphasis omitted).

29. United States v. Green, 405 F. Supp. 2d 104, 107 (D. Mass. 2005).

30. *E.g.*, Fletcher v. Lane, 446 F. Supp. 729, 731 (S.D. Ill. 1978).

31. *Resolution VII*, IDENTIFICATION NEWS, Aug. 1979, at 1. By prohibiting the use of qualified or probabilistic conclusions, fingerprint examiners compel themselves to give only absolute opinions. That is, they can testify only that they have "identified" the source of the fingerprint to a certainty, or they must refrain from giving an opinion on the source of the print.

32. *E.g.*, People v. Milone, 356 N.E.2d 1350, 1355-56 (Ill. App. Ct. 1976).

33. *E.g.*, ALBERT S. OSBORN, QUESTIONED DOCUMENTS 231, 261, 344, 381-84 (2d ed. 1929).

34. *E.g.*, WILLIAM J. BODZIAK, FOOTWEAR IMPRESSION EVIDENCE 3 (CRC Press 1995) (1990).

35. *E.g.*, William J. Bodziak, *Forensic Tire Impression and Tire Track Evidence*, *in* FORENSIC SCIENCE: AN INTRODUCTION TO SCIENTIFIC AND INVESTIGATIVE TECHNIQUES, *supra* note 28, at 377, 387-89.

36. Williamson v. Reynolds, 904 F. Supp. 1529, 1554 (E.D. Okla. 1995).

37. Saks & Koehler, *supra* note 9, at 892.

which different objects could share a common set of observable characteristics. In short, without the assumption of discernible uniqueness, far more scientific work would be necessary, and criminalists would need to offer more tempered opinions in court.

B. Origins and Evolution of the Notion of Individualization

Gottfried Wilhelm Leibniz (1646-1716) developed the ontological principle of the identity of indiscernibles ("Leibniz's Law").[38] This metaphysical principle states that if there is no way to tell two entities apart, they are one and the same entity. Although philosophers disputed the principle and offered counterexamples,[39] echoes of Leibniz's law appear in arguments for individualization.

The first potentially scientific notion of uniqueness originated with Lambert Adolphe Jacques Quételet (1796-1874), a Belgian statistician and sociologist best known as the father of descriptive social statistics.[40] Quételet hypothesized that "nature never repeats."[41] He based that notion on the product rule, a fundamental tool of probability theory that yields the joint probability of independent events by multiplying their separate probabilities.[42] When an object has many attributes, each of which can take on numerous different values, and each attribute is uncorrelated with every other attribute, there are long odds against the complete repetition of the attributes' pattern.

Alphonse Bertillon (1853-1914) learned of Quételet's theory from his father and grandfather, serious students of statistics, anthropology, medicine, and demography.[43] From his position as a records clerk with the Paris police, Bertillon overcame the resistance of his superiors and used Quételet's hypothesis to develop the first system of forensic identification, termed "anthropometry," or *bertillonage*.[44] Bertillon measured eleven different physical features of each prisoner and assembled the prisoner profiles into special files

38. Peter Forrest, *The Identity of Indiscernibles*, STAN. ENCYCLOPEDIA PHIL., (2006) http://plato.stanford.edu/archives/fall2006/entries/identity-indiscernible/.

39. *See, e.g.*, Max Black, *The Identity of Indiscernibles*, 61 MIND 153 (1952).

40. 9 NEW ENCYCLOPÆDIA BRITANNICA 855 (15th ed. 1990) (describing Adolphe Quételet).

41. *See* John I. Thornton, Letter to the Editor, *The Snowflake Paradigm*, 31 J. FORENSIC SCI. 399, 399 (1986) (referencing Quételet's hypothesis, but noting that Quételet actually used slightly different words from those in this quote commonly attributed to him).

42. Richard A. Posner, *An Economic Approach to the Law of Evidence*, 51 STAN. L. REV. 1477, 1512-14 (1999).

43. SIMON A. COLE, SUSPECT IDENTITIES: A HISTORY OF FINGERPRINTING AND CRIMINAL IDENTIFICATION 33-34 (2001).

44. *Id.* at 32-33; JÜRGEN THORWALD, THE CENTURY OF THE DETECTIVE 3, 9-13, 20-26 (1965).

reflecting their classifications.[45] If the prisoners were measured properly and if Quételet were correct, then Bertillon would be able to identify prisoners who had been arrested before and who were using aliases on re-arrest (to avoid longer sentences for being recidivists).

Pioneers in each forensic identification subfield followed the lead of Quételet and Bertillon by invoking the product rule to argue that no two of a certain type of object could be mistaken one for another. Thus, Balthazard argued for the uniqueness of fingerprints,[46] Osborn for handwriting,[47] Goddard for firearms,[48] May for toolmarks,[49] and so on. Proponents of these theories made no efforts to test the assumed independence of attributes, and they did not base explicit computations on actual observations. Indeed, they neither obtained nor offered empirical data of any sort to support the theories.

Sir Francis Galton is the one exception among forensic identification pioneers. A major early contributor to the study of fingerprints, Galton remains one of the few students of any of these techniques to attempt to collect empirical data and to subject the data to meaningful probabilistic analysis.[50] He never was convinced entirely of fingerprints' ability to individualize, and he never believed that the field to which he made such important contributions was scientifically superior to anthropometry.[51] This apparent irony will not seem ironic to conventional scientists, who know that those who perform empirical tests tend to be more sober about the phenomenon under study than those who merely theorize.

III. UNPROVED AND PERHAPS UNPROVABLE

Even without supportive data, various arguments have been offered on behalf of the individualization hypothesis. None are

45. COLE, *supra* note 43, at 34.

46. *No Two Finger Prints Alike*, 105 SCI. AM. 166 (1911).

47. OSBORN, *supra* note 33, at 231, 381-82.

48. Calvin H. Goddard, *Scientific Identification of Firearms and Bullets*, 17 J. AM. INST. CRIM. L. & CRIMINOLOGY 254, 262-63 (1926).

49. Luke S. May, *The Identification of Knives, Tools and Instruments a Positive Science*, 1 AM. J. POLICE SCI. 246, 246-47, 255 (1930).

50. For recent work which makes use of empirical data and subjects them to probabilistic analysis, see Nicole M. Egli et al., *Computation of Likelihood Ratios in Fingerprint Identification for Configurations of Three Minutia*, 51 J. FORENSIC SCI. 1255 (2006), which uses a database of 818 loops and 216 fingerprints from two donors to show that partial fingerprint matches produce large likelihood ratios, and Cedric Neumann et al., *Computation of Likelihood Ratios in Fingerprint Identification for Configurations of Any Number of Minutiae*, 52 J. FORENSIC SCI. 54 (2007), which tests a model for computing fingerprint identification likelihood ratios based on a sample of 686 loops and 204 arches.

51. *See* COLE, *supra* note 43, at 92.

scientifically compelling. Some arguments rely on the metaphysical notion that because no two objects can be the same object, they will inevitably manifest observable differences. Some rely on appeals to venerated authority (dead members of our field said it was so), contemporary authority (living members of our field say it is so), wishful thinking (because object variability has been observed, there will always be discernible differences between any two objects), or the personal experience of practitioners (as if by doing casework on pairs of objects the nature of the population and relationships within that population are revealed).[52] These approaches amount to nothing more than faith and intuition.

The only rigorous argument offered to support the hypothesis of individualization derives from the product rule, suggested by Quételet and relied on by those who founded the various subfields of criminalistics. According to the rule, the probability that each of a series of independent events will occur is given by the product of their unconditional probabilities.[53] Attempts to use the product rule to support individualization run into several problems. First, proper application of the rule requires a set of reliable frequency estimates for the relevant set of forensic characteristics. Second, the characteristics must be independent of each other. Third, even if the first two problems are overcome, application of the product rule necessarily falls short of establishing unique individualization. The product of probabilities greater than zero always yields a value greater than zero. The probabilistic approach, therefore, always leads to the conclusion that a source other than the suspected individual or object might exist.[54]

Alarmed by the prospect of courts following rigorous new judicial[55] and statutory[56] requirements for the admission of expert evidence, forensic scientists recently have undertaken studies intended to prove that no two sets of markings left by distinct objects can be indistinguishably alike. That such studies were not undertaken

52. Sandy A. Zabell, *Fingerprint Evidence*, 13 J.L. & POL'Y 143, 155-56, 162-63, 168-69, 176-179 (2005).

53. Posner, *supra* note 42.

54. *See, e.g.*, HAROLD CUMMINS & CHARLES MIDLO, FINGER PRINTS, PALMS AND SOLES: AN INTRODUCTION TO DERMATOGLYPHICS 150-55 (Dover Publications 1961) (1943); Stoney, *supra* note 24.

55. *See, e.g.*, Daubert v. Merrill Dow Pharm., Inc., 509 U.S. 579, 597 (1993) (requiring courts to engage in a "gatekeeping" role, inquiring into both the relevance and the reliability of the expert testimony); Kumho Tire Co. v. Carmichael, 526 U.S. 137, 138 (1999) (interpreting *Daubert* to apply not only to " 'scientific' testimony, but to all expert testimony").

56. FED. R. EVID. 702 (codifying a three-part test for determining whether to admit expert testimony). The Rule was amended in 2000 in response to both *Daubert* and *Kumho Tire*.

until this late in the history of these disciplines is remarkable. How did the practice get so far ahead of the science? Why could it be concluded, a century after fingerprint experts began testifying in courts, that "the suggestion that recorded fingerprints are unique has never been rigorously checked"?[57] The few existing studies were launched with the problematic goal of trying to prove empirically what for so long had been asserted on faith. Given the pressures that precipitated the studies, it is not surprising that, even when they fell short of proving what they set out to prove, they were proclaimed to have met their goals.[58]

For example, Lockheed Martin conducted the first noteworthy study aimed at proving the uniqueness of fingerprints at the request of the FBI in 1999.[59] Lockheed Martin undertook this project *during* the first case in which the admissibility of fingerprint identification testimony was challenged under *Daubert*.[60] In that study, each of 50,000 file prints was compared to itself and to the others in the file using the Automated Fingerprint Identification System ("AFIS"). The authors concluded that it is virtually impossible for any two fingerprints to be indistinguishably alike. But in a detailed critique of the study published in a statistics journal, David Kaye identified substantial errors in the study's design and analysis that cast serious doubt on its conclusions.[61] According to Kaye, this study—which, he notes, was "unpublished and prepared expressly for litigation"—provides "a lesson about probabilities generated for use in litigation: If such a probability seems too good to be true, it probably is."[62]

Sargur Srihari et al. conducted a study "to establish the individuality of handwriting."[63] The authors noted that such an inquiry never had been undertaken but was now necessary because of reliability concerns raised by the courts.[64] Even though the design of this study—a relatively small sample of writers and large samples of

57. BALDING, *supra* note 16, at 54; *see also* David H. Kaye, *Questioning a Courtroom Proof of the Uniqueness of Fingerprints*, 71 INT'L STAT. REV. 521 (2003); Stoney, *supra* note 3; Zabell, *supra* note 51, at 164-67.

58. See D. Michael Risinger & Michael J. Saks, *A House with No Foundation*, 20 ISSUES SCI. & TECH. 35 (2003), for examples of such studies.

59. Lockheed Martin Co., 50K vs. 50K Fingerprint Comparison Test (1999) (unpublished study).

60. *See* United States v. Mitchell, 365 F.3d 215, 223-26 (3d Cir. 2004) (outlining the details of the study done at the district court level).

61. Kaye, *supra* note 57, at 526-28.

62. *Id.* at 524, 528; *see also* Stoney, *supra* note 3, at 378-83; Zabell, *supra* note 52, at 164-67.

63. Sargur N. Srihari et al., *Individuality of Handwriting*, 47 J. FORENSIC SCI. 856, 857 (2002).

64. *Id.* at 856-57.

writing—favored distinguishing each writer from the others in the sample, the analysis fell short of its goal.[65] Even had the study succeeded within its own sample, it would not have answered the crucial question whether every writer in the population is distinct from every other writer. Indeed, this study has been critiqued in some detail.[66]

The claim of unique individuality cannot be proven with samples, especially samples that are a tiny proportion of the relevant population. As Balding commented: "It is impossible to prove any human characteristic to be distinct in each individual without checking every individual, which has not been done."[67] Anything less results in probability statements rather than conclusions of absolute specificity and absolute identification.

With no coherent theory to support the individualization hypothesis and few studies that attempt to test the hypothesis, proponents have looked for other evidence that arguably supports a claim of discernible uniqueness.[68] Some have seized on studies finding that monozygotic twins had discernibly different fingerprints.[69] If identical twins do not have identical fingerprints, proceeds the logic, then surely everyone else has distinguishable prints. Though appealing at first, reflection suggests that the uniqueness hypothesis would have found greater support if identical twins *did* have identical fingerprints. If that were true, one could argue that if the phenotype of fingerprints is isomorphic with the genotype, then whatever diversity exists in fingerprint genotypes will be reflected in fingerprint

65. *See id.* at 871.

66. Michael J. Saks, Commentary, *Individuality of Handwriting*, 48 J. FORENSIC SCI. 916, 916-17 (2003). The critique pointed out that, in fact, Srihari et al. had not found that each writer could be distinguished with certainty from every other writer in their sample, even though the design of the study made the likelihood of finding such distinctions unusually large, given: (1) the design of the sample (aiming to obtain a representation of writers spread across the United States, rather than from homogeneous writing communities); (2) the size of the inter-writer sample (much too small for the research question); (3) the size of the writing sample (far more words and forms and variations than encountered in virtually any forensic setting); (4) the size of the intra-writer sample (too small to capture the variation present within writers); and (5) reliance on cursive writing (so the study is irrelevant to many forensic instances of small amounts of hand printing or numbers). Moreover, the study involved no human examiners, only computer-based pattern recognition. *Id.* So whatever the study found, it could not tell us how well or poorly humans could distinguish one writer from another. (The authors assumed that humans could do better than the computer, but that remains an untested empirical question.) *Id.* at 917.

67. BALDING, *supra* note 16, at 54.

68. The reader is reminded that the phrase "discernible uniqueness" is merely a shorthand way to describe the criminalists' presumption that conclusions about object uniqueness are not only theoretically possible but attainable in practice. *See supra* text accompanying note 37.

69. *E.g.*, United States v. Mitchell, 365 F.3d 215, 223, 236 (3d Cir. 2004).

phenotypes. But if unspecified random and systematic events are interposed along the pathway from genotype to phenotype,[70] the need for a rigorous scientific approach that takes into account the probability of duplication becomes more, not less, necessary.[71]

Another argument offered in support of the object individualization hypothesis is that, in examining many pairs of objects in their casework, examiners have not yet come across two sets of markings produced by different sources that are indistinguishable from each other.[72] This observational argument has three shortcomings. First, as Karl Popper famously explained, it is logically impossible to prove a hypothesis by accumulating positive instances.[73] The hypothesis, "all swans are white," remains unproven, even after a large number of sightings of white swans, because the sighting of a single black swan would disprove it. Similarly, the hypothesis that no two objects are indistinguishably alike cannot be proven true from an accumulation of observations in which different object sources produce distinctive markings.[74]

The second weakness is that criminalists across disciplines have made no systematic, concerted effort to find different objects that produce identical markings. In casework, forensic examiners compare questioned marks to those of the suspect and, sometimes, to other persons involved in the case. Even a very large number of pairwise, case-by-case comparisons made by individual examiners would not provide a satisfactory method for testing the object uniqueness claim.

70. *See* W.J. Babler, *Prenatal Development of Dermatoglyphic Patterns: Associations with Epidermal Ridge, Volar Pad and Bone Morphology*, 11 COLLEGIUM ANTROPOLOGICUM 297 (1987) (performing an empirical study to test theories that the shape of volar pads on the finger of a fetus determines the ridge configuration on the finger and analyzing the results as suggesting possible support for the theories).

71. Handwriting examiners have also argued that differences in writing between identical twins support the conclusion that handwriting is unique. *See, e.g.*, United States v. Hidalgo, 229 F. Supp. 2d 961, 963 (D. Ariz. 2002) (referencing several such studies). The court found that the studies presented by the proponent did not support the proposition argued. *Id.* On the other hand, it is hard to understand why one should expect that having the same genotype would cause twins to write indistinguishably alike, and why a finding that they did not write indistinguishably alike would lead to the inference that no writings on earth are indistinguishably alike.

72. *See, e.g.*, United States v. Havvard, 117 F. Supp. 2d 848, 852, 854 (S.D. Ind. 2000) (concerning fingerprints); David L. Grieve, *Simon Says*, 51 J. FORENSIC IDENTIFICATION 85 (2001) (same).

73. KARL R. POPPER, THE LOGIC OF SCIENTIFIC DISCOVERY 33, 40-42, 62-63, 68-70, 252-54 (2d prtg. 1961).

74. *Cf.* Ronald G. Nichols, *Defending the Scientific Foundations of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges*, 52 J. FORENSIC SCI. 586, 592 (conceding that "individuality cannot be absolutely proven because it is impossible to examine every tool in the world to a tool mark in question").

To illustrate, suppose that exactly 100 pairs of firearms out of an estimated 100,000 guns in a Texas town share indistinguishable gun barrel markings. If each of 100 firearms experts examined 10 pairs of guns from the town's gun population every day for 10 years (n=3,650,000 gun pairs), there is about a 93% chance that none of the indistinguishable pairs will have come under examination. That is, despite 1,000 "collective years" of forensic science experience (100 experts multiplied by 10 years), the failure to find even a single pair of guns with indistinguishable markings would offer little basis for drawing conclusions about whether gun barrel markings, even in this single town, are unique. Examiners rarely search a large database for multiple possible matches. Indeed, very few subfields even have such databases. Conducting a serious search for matches, and failing to find any, would have strengthened markedly the observational argument. But under the available search conditions, falsification of the individualization hypothesis has been unlikely, and so the lack of falsification proves very little. As the size of a comparison database becomes larger, the object uniqueness hypothesis is subjected to an increasingly tough empirical test. If, under these circumstances, scientists still do not find indistinguishably similar matches produced by different objects, then object uniqueness becomes a more credible theory.

A third weakness is that indistinguishable markings produced by different objects already have been found in a number of forensic subfields. Consider, for example, an analysis of signatures taken from a voter registration database that revealed numerous indistinguishably alike signatures.[75] Similarly, cases have been documented in which the fingerprints of one person were identified as someone else's.[76] There also have been many false positive identifications of bitemarks.[77]

In sum, no sound and rigorous evidence supports the assumption of unique individualization. Moreover, the assumption is

75. John J. Harris, *How Much Do People Write Alike: A Study of Signatures*, 48 J. CRIM. L. & CRIMINOLOGY 647, 647 (1958) (finding that "many of these signatures lacked individuality and looked alike").

76. Simon A. Cole, *The Prevalence and Potential Causes of Wrongful Conviction by Fingerprint Evidence*, 37 GOLDEN GATE U. L. REV. 39, 57 (2006).

77. C. Michael Bowers, *Problem-Based Analysis of Bitemark Misidentifications: The Role of DNA*, 159 FORENSIC SCI. INT'L S104, S106-07 (Supp. 2006). Bowers observed that "dental experts seldom agree with one another at trial," citing controlled studies finding erroneous identifications or exclusions of between 24% and 91%, "63.5% false positives," and "false positive identifications of 11.9-22.0% for various groups of forensic odontologists." *Id.* He further cited seven cases in recent years where DNA typing contradicted the conclusions of forensic dentists that the defendant was the source of a crime scene bitemark. *Id.*

so heroic and the research required to test it seriously would be so massive that one must doubt whether it is possible to conduct an empirical study or set of studies that would provide solid support for the hypothesis.

IV. OLD NEWS

While criminalistics continues to depend on the theory of individualization and the assumption that it is attainable in practice, thoughtful and informed scientists long have recognized the lack of evidence for that core belief. In the 1940s, a team of biomedical researchers tried mightily to develop support for individualization in fingerprints, but ultimately concluded that "it is impossible to offer decisive *proof* that no two fingerprints bear identical patterns."[78] Nearly half a century later, David Stoney published an article entitled, *What Made Us Ever Think We Could Individualize Using Statistics?*[79] Elsewhere, Stoney has said: "The criteria for absolute identification in fingerprint work are subjective and ill-defined. They are the product of probabilistic intuitions widely shared among fingerprint examiners, not of scientific research. Outside of the fingerprint profession this is generally unappreciated."[80] Similarly, Thornton and Peterson observed:

> [T]hough individualization is clearly the goal toward which forensic science strives, it can be achieved only in a probabilistic sense, of reducing uncertainty to the smallest possible amount. . . . Behind every opinion rendered by a forensic scientist there is a statistical basis. We may not know what that basis is, and we may have no feasible means of developing an understanding of that basis, but it is futile to deny that one exists.[81]

An FBI Laboratory committee recently assembled "to evaluate the fundamental basis for the science of friction ridge skin impression pattern analysis" concluded that "[e]mpirical studies can never prove absolutely the hypothesis of uniqueness."[82] Also, in reference to

78. CUMMINS & MIDLO, *supra* note 54, at 154.

79. Stoney, *supra* note 24.

80. David A. Stoney, *Fingerprint Identification: Scientific Status*, *in* 4 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY, *supra* note 4, at 339, 358.

81. Thornton & Peterson, *supra* note 4, at 11, 32.

82. Bruce Budowle et al., *Review of the Scientific Basis for Friction Ridge Comparisons as a Means of Identification: Committee Findings and Recommendations*, 8 FORENSIC SCI. COMM. (2006), http://www.fbi.gov/hq/lab/fsc/backissu/jan2006/research/2006_01_research02.htm. The quoted statement is somewhat paradoxical. The claim of uniqueness is by definition "absolute," but the Committee suggests it must be accepted as true even if there is no way to provide "absolute proof." *See id.* One wonders why the FBI Committee didn't simply scale back the claim so it can stand on whatever ground is available to support it. The committee offered three lines of argument to justify belief in uniqueness: anecdotal evidence, comparisons of identical twins, and

fingerprint identification, European forensic scientists Christophe Champod and Ian Evett carefully have examined "a major contradiction between the scientific status that is claimed and the operational paradigm to which its practitioners subscribe."[83] They ask whether "a statement of an 'absolute conclusion' [can be] compatible with scientific reasoning" and whether "the denial of probabilistic reasoning [can be] compatible with a scientific pursuit."[84] They conclude that "an inductive process must be probabilistic" and that "denial of that state of affairs" is illogical and unscientific.[85] In the firearms and toolmark area, Alfred Biasotti, John Murdock, and Bruce Moran have noted that "existing research was insufficient to validate the quantitative objective criteria necessary to conclude that a working surface is unique."[86] Inman and Rudin allow that examiners in various subfields of criminalistics do not yet have the science to back up their claims, so they are merely "making the leap" to individualization.[87]

Why, then, do many criminalists ascribe greater powers to their fields than the research evidence supports? Part of the problem may be that most practitioners are not well schooled in the probabilistic nature of scientific claims. Or perhaps practitioners simply are not aware of the dearth of scientific support for their discipline's core assumptions. For example, evidence of dental uniqueness is limited to "a small number of journal articles which are less than persuasive in their efforts to prove uniqueness scientifically," yet "91% [of forensic dentists] support dental uniqueness and 78% believe that uniqueness transfers faithfully to human skin."[88] Or perhaps the adversarial environment in which most forensic scientists operate induces them to exaggerate the probative value of the evidence about which they are testifying. Whatever the explanation,

the "belief that the stresses, strains, and tensions across an area of friction ridge skin are random, infinite, and independent." *See id.* The weaknesses of each argument are addressed elsewhere in this Essay.

83. Christophe Champod & Ian W. Evett, Commentary, *A Probabilistic Approach to Fingerprint Evidence*, 51 J. FORENSIC IDENTIFICATION 101, 101 (2001).

84. *Id.*

85. *Id.* at 117.

86. Alfred Biasotti et al., *Firearms and Toolmark Identification: Scientific Issues*, *in* 4 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY, *supra* note 4, at 544, 565.

87. INMAN & RUDIN, *supra* note 27, at 123, 147-51.

88. C. Michael Bowers, *Identification from Bitemarks: Scientific Issues*, *in* 4 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY, *supra* note 4, at 625, 647-48.

the obvious question arises: What can be done to remedy the contradiction between knowledge and practice?

V. WHAT TO DO

Knowledgeable forensic scientists have recognized for quite some time that criminalists' belief in individualization is based on anecdote, intuition, and speculation rather than on scientific foundation. Consequently, individualizations in casework rely on a "leap of faith." To remedy this shortcoming, Inman and Rudin have called on the forensic science community "to produce a body of empirical work that can support that pragmatic leap of faith to a conclusion of a single common source."[89] But this puts the cart before the horse. Scientists and serious practitioners customarily refrain from making inferential leaps unjustified by data. They confine their statements to what is known and supportable, not to what they take on faith.

While waiting for the necessary knowledge base to develop, what can forensic scientists do to contribute to a fact-finder's understanding of the evidence in a case without exaggerating or distorting that contribution? Moreover, what can forensic and other scientists do to build the necessary scientific foundation?

A. The Present

For the present, when criminalists cannot distinguish a questioned pattern from a known pattern (i.e., when they judge a questioned and a known pattern to be indistinguishable or consistent, or to "match"), criminalists should report that finding with the appropriate clarity and restraint. For example, they could explain that a conclusion that two patterns are consistent (or a match) does not require a conclusion that the patterns share a common source. Once they have explained this point, criminalists should resist the urge to draw a source conclusion—or any other inference—that is not supported by sound theory and hard data.[90]

Examiners should explain that, in finding that two patterns match, they have placed the suspect object or person in a pool of one or more objects that match the evidentiary marks. The strength of the

89. INMAN & RUDIN, *supra* note 27, at 151.

90. Judicial thinking can be found that approximately parallels this restraint. *See, e.g.*, United States v. Llera Plaza, 57 Fed. R. Evid. Serv. 983, 1002-05, 1016-17 (E.D. Pa. Jan. 27, 2002), *vacated and superseded on reconsideration*, 188 F. Supp. 2d 549 (E.D. Pa. 2002); United States v. Hines, 55 F. Supp. 2d 62, 69-71 (D. Mass. 1999).

likelihood that the known object or person shares a common source with the questioned object or person depends on the size of the pool. No scientific justification exists for assuming that the size of the pool is one. And, for most areas of criminalistics (other than DNA typing and, potentially, fingerprinting), there are no empirically grounded estimates of how large such pools might be. Experts should not substitute their intuition or judgment in an effort to fill these knowledge gaps. The speculation of an examiner about the size of those pools is not scientific evidence.

Nevertheless, if a court encourages or permits an examiner to venture a guess about the size of the matching pool, the guess ought to reflect something akin to confidence intervals in statistics.[91] The interval should be set wide enough to have a high probability of including the actual number that might be in the pool. As the necessary research proceeds, those confidence intervals can narrow appropriately. But no data that could permit forensic scientists to offer an identification "to the exclusion of all others in the world" exist, and they are unlikely to come into being in the foreseeable future.[92] Such testimony is speculative and improper, both scientifically and legally.

B. The Future

For the future, traditional forms of forensic identification should begin to emulate the general model used in DNA typing. Whether geneticists believe in the biological uniqueness of individuals, they know that DNA tests examine only a fraction of the genome. Even if two DNA samples match on a dozen or more alleles, geneticists know that the samples might not share a common source because differences might exist between the samples on untested alleles. They also know that their data reflect samples of people, not genetic censuses of the human population.[93] The solution to this problem in DNA typing has been a frank reliance on probability: the population (and subpopulation) frequencies of the observed genetic attributes are estimated through sampling; the independence of those attributes is verified; and the product rule is applied to the individual

91. *See generally* David H. Kaye & David A. Freedman, *Reference Guide on Statistics*, *in* FED. JUDICIAL CTR., REFERENCE MANUAL ON SCIENTIFIC EVIDENCE 83, 90, 115-21 (2d ed. 2000) (outlining specific concerns presented by experts drawing inferences from their statistical data when testifying); David H. Kaye & David A. Freedman, *Statistical Proof*, *in* 1 MODERN SCIENTIFIC EVIDENCE: THE LAW AND SCIENCE OF EXPERT TESTIMONY, *supra* note 4, at 219, 231-32, 274-79 (same).

92. *See supra* text accompanying notes 29-36.

93. As one sometimes sees in televised forensic science fiction.

frequencies to determine the joint probability of the occurrence of that set of attributes in the population. This latter estimate then is reported to fact-finders to help them assess the probative value of the DNA evidence.[94]

Similar procedures, in principle, can be employed for other materials of forensic interest: fingerprints, handwriting, bitemarks, toolmarks, and so on. Criminalists face two challenges in developing such procedures. One challenge will be developing valid and reliable measures of the images of interest—of friction ridges, of toolmark striations, of bitemarks, of writing. A second challenge will be developing databases that identify the frequency with which various images appear. In some areas (e.g., toolmarks, firearms, and shoeprints), the challenge of producing sound probability estimates may be especially difficult because the materials change over time and with use.

VI. CONCLUSION

This Essay challenges the conventional wisdom about the capabilities of the forensic identification sciences. Forensic scientists are not able to link a fingerprint, a hair, a handwriting sample, a tiremark, a toolmark, or any other evidentiary forensic item to its unique source, but they assert that ability every day in court. The issue is not the sincerity of the beliefs of workaday forensic scientists. Instead, it is whether any scientific evidence exists that can support those beliefs. No basis exists in theory or data for the core contention that every distinct object leaves its own unique set of markers that can be identified by a skilled forensic scientist. Their claims exaggerate the state of their science. This sort of exaggeration, combined with public credulity, is the classic reason that common law evidence doctrine required a heightened threshold for admission of expert testimony. Under Rule 702 of the Federal Rules of Evidence, as interpreted by *Daubert* and *Kumho Tire*, such testimony would be a prime target for exclusion.[95] But, short of exclusion, the legal community would do well to understand the individualization fallacy,

94. Although the DNA typing model has much to offer the traditional forensic sciences, offering source identifications at trial for sufficiently low probabilities would not be an implication of the science but an evasion of it in the service of advocacy. *See* Bruce Budowle et al., *Source Attribution of a Forensic DNA Profile*, 2 FORENSIC SCI. COMM. (2000), http://www.fbi.gov/hq/lab/fsc/backissu/july2000/source.htm.

95. Kumho Tire Co. v. Carmichael, 526 U.S. 137, 138 (1999); Daubert v. Merrill Dow Pharm., Inc., 509 U.S. 579, 580 (1993). FED R. EVID. 702 requires that expert testimony be "based upon sufficient facts or data." The existing facts and data do not demonstrate that forensic scientists can identify a unique set of markers for every distinct object.

encourage reforms designed to put a scientific foundation beneath forensic identification, and place appropriate limits on what expert witnesses may assert. Forensic identification scientists can help themselves immediately by forswearing exaggerated, definitive conclusions in favor of humbler, scientifically justifiable, and probabilistic conclusions.