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# Forensics without uniqueness, conclusions without individualization: the new epistemology of forensic identification†

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Among the causes of the current sense that the forensic identification disciplines are 'under siege' are conceptual difficulties in these disciplines. Forensic identification disciplines either claim to achieve or strive to achieve conclusions of 'individualization', the reduction of the donor pool to a single source. They tend to support such claims by reference to the supposed 'uniqueness' of their objects of analysis. Both these notions remain extremely salient among practitioners and courts. And yet, a broad consensus in the forensic literature holds that individualization is unachievable and uniqueness is largely irrelevant to supporting claims of individualization. Focusing on latent print evidence, this article provides a clear articulation of the need to make a clean break from both individualization and uniqueness as forensic concepts. It argues that trace evidence disciplines can live without these concepts, and it explores what defensible conclusions might look like and how they might be supported.

*Keywords:* individualization; unique; forensic identification; philosophy; epistemology; fingerprint.

An object can be identical only to itself.
– Gottfried Wilhelm Leibniz (1686)

Criminalistics is the science of individualization.
– Paul Kirk (1963)

Roughly speaking, to say of two things that they are identical is nonsense, and to say of one thing that it is identical with itself is to say nothing at all.
– Ludwig Wittgenstein (1922)

"A thing is identical with itself." – There is no finer example of a useless proposition.
– Ludwig Wittgenstein (1953)

Science cannot utter a single word about an individual molecule, thing, or creature in so far as it is an individual but only in so far as it is like other individuals.
– Walker Percy (1954)

We're one, but we're not the same.
– U2 (1991)

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## 1. Introduction

Recent years have seen increasing controversy over what I will call here *forensic identification techniques*, such as the analysis of latent prints, tool marks, bite marks, handwriting and shoe print identification as well as other impression evidence techniques. Forensic analysts use forensic identification techniques to contribute to forensic investigations by making *inferences of common source* between an evidentiary trace and reference sample, whose origin is known (Kwan, 1977; Champod, 2000; Inman and Rudin, 2001: 137–139).[1] In criminal cases, these inferences frequently translate into reports or testimony of what I will here call *source attribution*—testimonial claims that a particular trace was made by a particular source object.

There is a widespread sense that forensic science—and, in particular, forensic identification—is 'under siege' (Pyrek, 2007). This sense of siege might be attributed to a number of causes including: claims that many techniques lack basic validation; concerns about accreditation, certification, quality control and standard setting; concerns about overclaiming in testimony; concerns about a lack of basic research and commitment to scientific norms; and concerns about errors. This article will not discuss those concerns. Instead, it will focus on another issue that, I will suggest, is among the most important issues at the root of the current sense of crisis in forensic identification: the epistemological foundations of forensic identification.

By this, I mean what sorts of things forensic analysts claim to know—what 'knowledge claims' they make—and how we know whether they can, in fact, know these things. Historically, forensic scientists have written a number of treatises under the rubric of what they have variously called the 'ontogeny of criminalistics' (Kirk, 1963)[2] or the 'philosophy of identification' (Huber, 1972). But, these works fail to provide an epistemological foundation for forensic identification knowledge claims. This does not, however, mean that forensic identification could not benefit from serious consideration of how forensic identification experts might be able to vouch for the things the claim to know. Indeed, some forensic practitioners have suggested that philosophy can 'contribute to our forensic sciences' (Vanderkolk 2002). This article suggests that some of the current sense of crisis in forensic identification may be attributed to a historical failure to articulate defensible epistemological foundation for the testimonial claims that forensic identification experts make. It suggests that forensic identification might benefit from taking epistemology seriously, and it points towards a way forward to defensible testimonial claims.

This article suggests that forensic identification—historically and still today—rests upon indefensible conceptual foundations. Specifically, it will focus on two conceptual pillars of forensic identification: the notions of 'individualization' and 'uniqueness'. I will show that these two notions are, in fact, believed by both practitioners and legal actors[3] to constitute the conceptual foundations of forensic identification. Paradoxically, however, I will then show that a broad consensus in the scholarly literature rejects the notion that individualization and uniqueness constitute the proper conceptual foundations for forensic identification (see, e.g. Kwan, 1977; Robertson, 1990; Stoney, 1991; Starrs, 1999; Champod and Evett, 2001; Inman and Rudin, 2001; Thornton and Peterson, 2002;

[1] I prefer Inman and Rudin's term 'common source' to Kwan and Champod's 'identity of source' because it avoids the term 'identity' whose loaded nature will be discussed throughout this article.

[2] As suggested by the title, Kirk was less concerned with epistemology than with articulating what he thought were the fundamental principles of criminalistics.

[3] I use the sociological term 'actor' to denote people who function within the legal system. Readers may safely construe the term 'legal actor' to mean, essentially, 'attorney, judge, or juror '.

Meuwly, 2006; Biedermann *et al.*, 2008; Saks and Faigman, 2008; Saks and Koehler, 2008). This scholarly consensus, however, has not dissuaded forensic practitioners or legal actors from continuing to rely on both these notions.

Although many of the arguments made here have been made by other scholars, this article seeks to distill a clear articulation of why individualization and uniqueness cannot constitute the conceptual foundations for forensic identification. It concludes by arguing that continued adherence to these notions contribute to the sense of 'siege' in forensic science by causing miscommunication between scholars and practitioners about what empirical data is necessary to support the sorts of testimonial claims forensic identification experts would like to be able to make and by impeding progress towards developing empirical support for such claims. The article will emphasize latent print (fingerprint) identification, which is the discipline that most clearly and explicitly rests upon the notions of individualization and uniqueness, but most of what it has to say applies to other forensic identification disciplines as well.[4]

## 2. Individualization

Criminalistics, was famously defined by Kirk (1963) as 'the science of individualization'. More recently, Inman and Rudin (2001: 123) have called the concept of individualization 'the hallmark of our profession'. Individualization is understood to mean the narrowing of possible sources of a forensic trace to a single object in the universe. In this sense, 'individualization' is meant to be distinguished from more modest claims of 'identification' in which the potential source is narrowed only to a group (or 'class') of objects (Inman and Rudin, 2001: 115; Thornton and Peterson, 2002: 8).[5]

Today, individualization is defined by the Scientific Working Group on Friction Ridge Analysis, Science and Technology (SWGFAST) as 'The determination that corresponding areas of friction ridge impressions originated from the same source to the exclusion of all others (identification)' (Scientific Working Group on Friction Ridge Analysis Study and Technology, 2003).[6] It is the only conclusion indicating possible commonality of source between two impressions that is permitted to professional latent print examiners. In other words, latent print examiners are not permitted, according to both SWGFAST and resolutions of the International Association for Identification (IAI), to report probabilistic conclusions or conclusions that source of a trace has been narrowed to a suspect's friction ridge skin and some other number of areas of friction ridge skin. Other forensic disciplines offer similar conclusions. Toolmark examiners use the term 'identification' to claim that the likelihood that a mark was made by another tool is so low it can be dismissed (Schwartz, 2005; Nichols, 2006: 590; Carroll, 2009), and bitemark examiners make source attributions "to a reasonable degree

[4] Forensic DNA profiling is also forensic identification technique, but it is in some regards, though not all, an exception to some of the remarks I will make here.

[5] We will bracket for this discussion the important issue of whether, forensic scholars' fine distinction notwithstanding, laypersons, including jurors, might understand by the word 'identification' precisely that which is supposedly meant only by 'individualization'. Note also that, according to these definitions, what some scholars have called the 'diagnosticity' of 'identification' is left extremely vague. 'Identification' could as easily indicate a narrowing of potential sources to a class of two objects or two million. In addition, it should be noted that in some disciplines the term 'identification' appears to be used in a manner synonymous with 'individualization', rather than in a manner consistent with the distinction drawn by Inman and Rudin and Thornton and Peterson.

[6] Notice, of course, that forensic scholars' careful distinction between "individualization" and 'identification' is obliterated here. The testimony in a recent admissibility hearing on latent print evidence illustrates the ambiguity as to whether SWGFAST understood the terms to be synonymous or distinct *(State v. Hull, 2008)*.

of medical certainty" that are very close to individualizations (Bowers, 2002). Shoe and tire analysis and handwriting analysis also strive for individualization (Huber and Headrick, 1999; SWGTREAD, 2006).

Claims of "individualization" pose an epistemological problem: how is it possible to know that two particular traces were made by the same source object? As we shall see below, most scholars believe the question cannot be answered definitively. Historically, however, in practice, the question has largely been answered by reference to uniqueness.

## 3. Uniqueness as Support for Individualization

Perhaps nothing is more closely associated with fingerprint identification than the popular notion that "no two fingerprints are alike." However, it is not merely the general public that relies upon this notion; forensic scientists themselves regard the uniqueness of material objects as a fundamental premise whose truth is necessary for forensic analyses to proceed. Thus, Kirk (1963) said "all objects in the universe are unique. If this were not true, there could be no identification in the sense used by the criminalist." And, more recently, Inman and Rudin (2001: 123) have said "Our belief that uniqueness is both attainable and existent is central to our work as forensic scientists."

Indeed, it is clear that, in contemporary forensic practice and judicial decision-making, the supposed uniqueness of forensic objects is used to justify, or "warrant" (Denbeaux and Risinger, 2003), claims of individualization. Let us begin by considering what is perhaps the paradigmatic forensic identification technique, latent print identification. We find that the notion that claims of individualization may be supported by evidence of the uniqueness of the target objects of analysis—what I have called elsewhere the 'fingerprint examiner's fallacy' (Cole, 2004b: 1197) and Saks and Koehler (2008) call the 'individualization fallacy'[7]—may be found at all stages of the processing of latent print evidence from the laboratory through the legal process and into the realm of scientific research. Latent print practitioners consistently and nearly without exception (but see, e.g. Templeman, 2008) invoke uniqueness when called upon to justify claims of individualization (Cole, 2006a).[8] In the

[7] It may be helpful here to disambiguate Saks and Koehler's 'individualization fallacy', Balding's (2005) 'uniqueness fallacy' and my 'fingerprint examiner's fallacy'. The 'uniqueness fallacy' refers to the false conclusion that all objects (e.g. fingerprints and DNA profiles) must be unique if the number of potential combinations of variables exceeds the relevant population (e.g. of human beings). Although Saks and Koehler (2008) do not explicitly define "individualization fallacy," which they call "a fundamental and more pervasive cousin of Balding's uniqueness fallacy" (205), elsewhere (Saks and Koehler, in press) they clarify that it concerns inferring individualization from a forensic analyst's conclusion that two traces are consistent. This differs slightly from what I have called 'fingerprint examiner's fallacy', in which individualization is inferred from claims of uniqueness.

My argument in this paper is almost entirely consistent with the argument laid out in Saks and Koehler (2008). My differences primarily have to do with issues of what I perceive to be clarity. First, in places, their paper does not always make it entirely clear that the problem of uniqueness is not merely that it is unattained but, further, that, even if attained, it would not support claims of individualization. Second, do not call explicitly for the abandonment of the terms 'uniqueness' and 'individualization' in forensic science, and, indeed, elsewhere (Saks and Koehler, 2005) they coin the neologism 'discernable uniqueness'. I fear that, by not explicitly calling for the disavowal of the terms, Saks and Koehler are unlikely to convince forensic scientists to abandon the fruitless quests for proof of both uniqueness and individualization. Third, Saks and Koehler (2008) occasionally conflate the notions of uniqueness and individualization, as when speaking of, e.g. 'unique and absolute identification' (205) and 'unique individualization' (214), a term that makes little literal sense. I treat uniqueness and individualization as separate, through related, concepts: individualization is a testimonial claim, and uniqueness is the supposed empirical or logical support for it.

[8] For example, at the presentation of an early draft of this paper at the Seventh International Conference on Forensic Statistics and Inference, at the conclusion of my presentation, in which I repeatedly emphasized the illogical nature of supporting

latent print practitioner literature, the 'uniqueness of human friction ridge skin' is characterized as one of 'the fundamental principles upon which the science of latent print examination are [*sic*] based' (Wertheim, 2002). Moreover, it is claimed that uniqueness establishes the validity of claims of individualization: 'The fact is, biological uniqueness allows us the liberty to identify persons through the comparisons we conduct' (Wertheim, 2001b).

In latent print examiners' sworn testimony, uniqueness is commonly invoked to support not only the claimed accuracy of conclusions of individualization but, further, the claim that such conclusions are infallible:

> And we profess as fingerprint examiners that the rate of error is zero. And the reason we make that bold statement is because we know based on 100 years of research that everybody's fingerprints are unique, and in nature it [*sic*] is never going to repeat itself again (Testimony of William Leo, *People v. Gomez*, *2002*: 270).

In trial court rulings, courts have reasoned that the accuracy of latent print analysis may be inferred from the uniqueness of human friction ridge skin. Indeed, it is suggested that this inference of accuracy is so persuasive that empirical testing of the accuracy of latent print analysis is not even necessary: '[I]f it is acknowledged that fingerprints are unique and permanent, then the theory of fingerprints, that everyone has one which can be compared with unknown prints seems to be sound and not in need of testing in the way described by Llera Park [*sic*] I' (*United States v. Merritt*, *2002*). In appellate court rulings as well, the view may be found that to assess the accuracy of latent print analysis, the only thing it is necessary to know is whether all friction ridge skin is unique: 'the underlying theory of fingerprinting evidence [*sic*]', is 'that all fingerprints are unique', and 'the Government's expert testified to the existence of numerous studies supporting this conclusion' (*United States v. Rogers*, *2001*).[9]

Even in some scholarly literature, legal proceedings contesting the accuracy of latent print analysis were misconstrued as contests over the uniqueness of human friction ridge skin, rather than over the accuracy of latent print individualization: 'Fingerprint identification was first challenged by the defense lawyers under *Daubert* in the 1999 case of USA versus Byron Mitchell on the basis that the fundamental premise of fingerprint *uniqueness* has not been objectively tested and the potential error rate in fingerprint matching is unknown' (Pankanti *et al.*, 2002, original emphasis; see Cole, 2006a:113, showing that the defendant stipulated to the issue of uniqueness but challenged accuracy in this case).

Even the National Institute of Justice, the U.S. funding agency best positioned to fund forensic research, has espoused the reasoning that claims of individualization may be supported by claims of the uniqueness of human friction ridge skin. In a letter concerning latent print research, a claim about expressing 'the already existing basis that permits fingerprints to be used as a means to individualize', was supported by the statement 'that it is accepted that fingerprints are unique to the individual'. (Samuels, 2000).

claims of individualization with arguments about uniqueness, in the question period a practitioner repeatedly invoked the uniqueness of friction ridge skin as a counterargument to my points. The same thing occurred after an earlier presentation at the Innocence Project New Zealand Conference 2007.

[9] These assertions about 'numerous studies supporting this conclusion' are perplexing given the difficulty of proving uniqueness. Although there are studies demonstrating that the exact duplication of complete rolled or partial fingerprint patterns is unlikely (for a review, see Stoney, 2001), there are no studies demonstrating that all human fingerprints are unique, nor is it clear that there could be such a study. The court offers no citations to guide us as to which "studies" the witness was referring.

A recent statement by the IAI, the largest professional organization of latent print examiners in the world, to a Committee addressing the validity of latent print analysis convened by the U.S. National Academy of Science (NAS), the most prestigious scientific body in the United States, claimed that 'unique anatomical features…have become the foundation upon which the individualization of a fingerprint to a single person becomes scientifically accepted and legally defensible' (International Association for Identification, 2007a).[10] Thus, as recently as 2007, the major professional organization of latent print examiners continued to publicly espouse the view that claims of individualization are justified by assertions of uniqueness. This view was also held by Scientific Working Group on Friction Ridge Analysis, Science and Technology (2004), which stated that 'Reliability of fingerprint examination is supported by the theories of biological uniqueness and permanence, probability modeling, and empirical data gained through over one hundred years of operational experience.'[11] Even more extraordinarily, the IAI stuck with this position even after the NAS explicitly rejected the notion that reliability may be demonstrated by reference to uniqueness (National Research Council, 2009: 1–7, 5–13). In a letter in response to the NAS report, the IAI replied, 'Over the years a number of research projects have been conducted. None of those projects refuted the scientific principle that fingerprints are unique and permanent' (Garrett, 2009). Thus, apparently even the NAS has been unable to dissuade practitioners from the belief that uniqueness support individualization.

These issues are by no means limited to fingerprint identification. Other forensic disciplines claim to be able to achieve individualization—not surprisingly because, recall, Kirk exhorted that all forensic disciplines should aspire to individualization. Thus, the discipline of toolmark examination, although unlike latent prints it does not explicitly ban probabilistic testimony less strong than 'individualization', allows conclusions of 'identification to the exclusion of all other tools' (Biasotti and Murdock, 2002: 212; see also Schwartz, 2005; Nichols, 2006). How do toolmark examiners support such claims? In a presentation to the NAS Committee, a toolmark practitioner testified: 'The basis of a toolmark identification is founded on the principle of uniqueness, wherein, all objects are unique to themselves and thus can be differentiated from one another' (Striupaitus, 2007). As it was for latent prints, this was a crucial moment in the history of toolmark identification in which it was called before a prestigious scientific body to account for its evidentiary claims.

Similarly, in many other forensic disciplines we can find both, first, the claim that some class of objects are 'unique' and, second, the claim that the accuracy of the technique can be inferred from that presumed uniqueness. Many forensic odontologists claim that all human dentition is unique (Bowers, 2002: 262). U.S. Federal Bureau of Investigation experts in comparative bullet lead analysis claimed that each 'melt' of lead contained a unique chemical composition (National Research Council, 2004: 9). It has been claimed that each human ear produces a unique ear print (Iannarelli, 1989), each elbow a unique elbow print (Oatess, 2000), and each human lip a unique lip print (Kasprzak, 1990).

Many of these disciplines have claimed that this supposed uniqueness vouches for the accuracy of the technique. Consider, e.g. the case of 'elbow print identification'. Oatess (2000: 132–133) writes

[10] Whatever the terms 'scientifically accepted and legally defensible' are supposed to mean empirically. It would have been more reassuring if the IAI had said 'accurate ' or 'valid'.

[11] To be clear, the probability models referred to are those that find unlikely exact duplication of complete rolled fingerprints (for a review, see Stoney, 2001) or partial prints (Neumann *et al.*, 2006, 2007). The 'empirical data' referred to is nothing more than the collective experience of latent print examiners in performing casework. For a discussion of the treatment of casework as empirical data, see Cole (2006b; a).

that 'the combination of my belief in the uniqueness of nature, along with the latent print training that I had received. . . enabled me to undertake the challenge' of making a testimonial source attribution 'that the suspect's left elbow *was* the source that made the latent elbow print' (135, emphasis added). As support for this claim, Oatess offers the notions that 'The idea that everything in nature is unique is well established among top experts in the identification field' (135) and that 'Until someone is able to show me that everything is nature is not unique unto itself, I'm a firm believer that prints made by living entities are only capable of having been made by the source' (136).[12] This illustrates the way in which the historical reliance upon uniqueness by paradigmatic disciplines like latent prints have habituated forensic analysts to thinking of uniqueness, rather than accuracy or rarity of features, as the relevant empirical question raised by testimonial claims of source attribution.

In sum, claims of individualization supported by claims of uniqueness are pervasive in contemporary forensic identification practice. Moreover, practitioners, funding agencies and legal actors appear to share the view that uniqueness can provide a defensible epistemological foundation for forensic testimonial claims of source attribution. What makes the pervasiveness of all of these claims somewhat surprising is that they are inconsistent with the scholarly literature on forensic science and evidence. In the next two sections, I will discuss the criticisms of these notions in the literature.

## 4. Critiques of uniqueness

The uniqueness rationale has been widely criticized by numerous scholars. These criticisms fall into two general camps. The first line of criticism argues that the uniqueness of target objects remains unproven. The second goes further and holds that uniqueness is largely irrelevant to assessing the probative value of a forensic assay.

### 4.1 *Uniqueness is unproven*

On the face of it, a uniqueness claim would seem to founder upon the problem of induction: it is not possible to observe all possible target objects, and, therefore it is no more possible to prove that all human friction ridge patterns are unique than it is to prove that there are no black swans. And so, some scholars have criticized the advancing of supposedly 'unproven and perhaps unprovable' (Saks and Koehler, 2008: 208) uniqueness claims (Kent, 2006; Meuwly, 2006: 207; National Research Council, 2009: 1–7).

In the face of this problem, a number of alternative proofs of uniqueness have been attempted. One argument is to claim that, though uniqueness cannot be deduced, it is possible to make what Kwan (1977: 27) calls 'inductions from simple enumeration'. Thus, the collecting and observing of fingerprints by law enforcement agencies without the discovery of any exact duplicate provide strong inductive evidence that no exact duplicates exist. Thus, e.g. Moenssens argues, 'if exact pattern duplication were to exist in the world at least a single instance of this would have been discovered by now'. Therefore, Moenssens concludes, 'it would be rather ludicrous to argue that the premises underlying fingerprint identification have not been scientifically validated in the face of

[12] This latter claim, of course, does not require 'belief' since it is tautological; obviously, a print can only be made by one source, just as an eyewitness can only have seen one person. The statement misses the crucial question: whether the analyst can correctly identify the source. This empirical question is not addressed by reference to uniqueness, but rather by reference to empirical data on Oatess's ability to make correct source attributions. In this case, that data showed that Oatess made correct identifications of the true source of seven elbow prints in seven target-present attempts from a reference database of 24 elbow prints (134).

the accumulated experience of the millions of fingerprints that have been scrutinized by experts' (Moenssens, 1999; see also German, 2002).

Critics of such claims point out that they are founded upon the accumulation of observations carried out by multiple observers that were not recorded or compiled. Thus, it is by no means clear that an individual latent print examiner, say, would be cognizant of finding a duplicate friction ridge skin pattern, if she had observed the duplicate pattern 20 years earlier. Similarly, two different latent print examiners observing duplicate friction ridge skin patterns would not be aware of the duplication.

For example, McLachlan (1995: 13) rhetorically asked:

> Of all the sets of fingerprints which are held on record by police forces throughout the world, have tests been conducted on them in order to see whether or not, even within this tiny sample of human fingerprints, there are two identical sets? I do not believe that such an experiment has ever been carried out. Has such an experiment been carried out? What were its findings? Have they been published? Do those people who claim to know that no two sets of human fingerprints are identical know of the carrying out of such an experiments and its published result?

Therefore, he concludes, uniqueness 'is more like a highly dubious snatch of metaphysics, a philosophical assumption than what it is presented as being: a hard-headed scientific conclusion' (18). To be sure, modern computer-searchable databases offer some potential for carrying out experiments that might allow a reasonable induction of 'practical' uniqueness, but there have been few such experiments thus far (Pankanti *et al.*, 2002). Moreover, even such experiments can never prove uniqueness; they can only establish that duplication is highly unlikely. In any case, the claim of uniqueness far predates these experiments, so it presumably does not rest upon them.

A second alternative proof holds that uniqueness may be demonstrated through knowledge of how friction ridge skin patterns are formed. Anatomical studies have detailed the process through which friction ridge skin is formed, and anatomists have asserted that, while the gross pattern type is genetically influenced, the ridge details that, according to latent print examiners, are unique are the product of contingent variations in temperature and pressure in the embryonic environment. From this 'infinite variation' (Moenssens, 2003: 32), some scholars and practitioners conclude that all human friction ridge skin patterns must be unique (see also Wertheim, 2002). Such conclusions would not seem to follow obviously from the evidence. First, the anatomical evidence would only seem to suggest that time, temperature and pressure are variables in the production of friction ridge skin. While this knowledge alone might provide for significant variation, we would need to know more about the scope of variation before concluding that the variation is 'infinite' or even extremely large. Anatomists do not provide data from which to more precisely estimate the variability of friction ridge skin patterns. Second, as McLachlan (1995) noted, to conclude 'that each person must have unique fingerprints on the grounds that the causal process which produces fingerprints is itself unique in each instance… would seem merely to beg the question at issue rather than answering it' (12). As McLachlan argues, even if each finger arrives at its friction ridge pattern through a unique causal pathway, there is no logical basis to assume that two fingers cannot arrive at identical patterns through different causal pathways. Indeed, it has been suggested that the random genesis of friction ridge skin actually should make us less confident in uniqueness than we would be if we believed that they were determined solely by genetic factors (Saks and Koehler, 2008: 211–212; Bowers, 2002: 256–257).

A third line of argument consists of attempts to statistically estimate the likelihood of exact duplication of a given area (usually a complete single finger bulb) of friction ridge skin. There have

been numerous such estimates, but few have been empirically tested (Stoney, 2001). Even so, such estimates can never prove uniqueness but only indicate that the likelihood of duplication is extremely small (Saks and Koehler, 2008). Some scholars have argued that when the inverse of the likelihood of exact duplication exceeds the population of fingerprints, one can claim that the uniqueness claim has been demonstrated (Kwan, 1977: 27; Saferstein, 2001: 73). But others have argued that there is nothing statistically magical about exceeding the population (Saks and Koehler, 2008), although some contend that uniqueness *can* be inferred if the likelihood of duplication is several orders of magnitude smaller than the population (Balding, 2005: 148; Kaye, 2009).

Perhaps the most common argument holds that uniqueness is supported by a supposed law of nature, that 'nature never repeats itself'. This idea has been variously attributed to a number of thinkers including Heraclitus, Parmenides, Zeno, Plato and Leibniz, whose Principle of the Identity of Indiscernables stated that 'an object can be identical only to itself', and Quetelet, who stated that 'Nature exhibits an infinite variety of forms' (Mairs, 1945; Bridges, 1946; Thornton, 1986; Tuthill, 1994: 17; McRoberts, 1996). It is not clear that this really is a law of nature. It might reasonably be argued that forensic practitioners have misconstrued, if not Quetelet, at least Leibniz, who was focusing less on the metaphysical uniqueness of material objects than on the impossibility of more than one object occupying the same time and space. It was this that provoked fingerprint pioneer Henry Faulds to characterize the argument for the uniqueness of complete single fingerprint patterns as 'the teaching of Leibniz badly understood' (Faulds, 1905: 53). However, as I will show in Section 4.3, even if forensic practitioners' interpretation of Leibniz were correct—i.e. even if there were some sort of 'natural law' of non-duplication—it could not be used to support claims of forensic identification.

In any case, arguing that claims of the uniqueness of various forensic objects are 'unproven and perhaps unprovable' is not the best argument against the claim that uniqueness provides an epistemological foundation for testimonial claims of source attribution. For one thing, the 'unproven' critique is undesirable because it puts its proponents in the logically correct but intuitively implausible position of doubting that all human friction ridge patterns are unique. As I will show in Section 4.3, the claim 'all friction ridge skin is unique' is clearly true, though banal, simply based on the definition of the term 'unique'. Second, such critiques are likely to prompt responsible proponents of various forensic assays to assume—incorrectly, as will be shown in the next section—that their task is to find a way to prove uniqueness. Thus, such arguments are likely to mire the field in unproductive debates about whether or not uniqueness is true or proved. More persuasive—and more conducive to progressing towards a more reasoned discourse in forensic science—are arguments that hold that uniqueness is largely irrelevant to individualization and cannot support claims of source attribution.

### 4.2 *Uniqueness is largely irrelevant*

As demonstrated above, historically–and still today–claims that forensic analysts can determine the true sources of latent prints to the exclusion of all other possible sources in the universe have been supported by reference to the supposed uniqueness of all human friction ridge skin. Such arguments may be critiqued on the basis that the premise—the uniqueness of all human friction ridge skin—remains unproven. However, such critiques do not go far enough because they suggest that the argument can be rehabilitated by proof (or perhaps by inference) of uniqueness. In fact, the

argument suffers from a more fundamental flaw in reasoning, which is that the accuracy of source attributions cannot be inferred merely from the uniqueness of the object of analysis.

What I have called 'the fingerprint examiner's fallacy' and Saks and Koehler have called 'the individualization fallacy' consists of using a claim of uniqueness as evidentiary support for a claim of individualization (Cole, 2004b: 1197). For example:

[A]. All human friction ridge skin is unique.

[B]. All the friction ridge detail in the mark is 'consistent' (within whatever parameter govern 'consistency') with the ridge detail in the exemplar print.

[C]. Therefore, the mark and the print share a common source.

The reasoning is fallacious. [C] does not actually follow logically from [A] + [B]. Numerous other scholars have articulated the principle that the uniqueness of the target object is almost entirely irrelevant to the accuracy of the attribution process (Robertson, 1990: 255; Champod and Evett, 2001: 115; Inman and Rudin, 2001: 54; Mnookin, 2001; Stoney, 2001; Bowers, 2002: 262; Thornton and Peterson, 2002: 25; Balding, 2005: 54; Budowle *et al.*, 2006; Meuwly, 2006: 207; Saks and Faigman, 2008: 155; Saks and Koehler, 2008; National Research Council, 2009: 1–7). In sum, the forensic literature consistently holds that evidence of the uniqueness of target objects is not the necessary empirical data to support testimonial claims of source attribution. The only groups that do *not* hold this view are, in some sense, the ones that matter most: practitioners and legal actors.

### 4.3 *Uniqueness is banal*

Though forensic scholars have clearly shown that uniqueness alone cannot support claims of source attribution, even irrelevance arguments do not go far enough. In this section, I want to argue that "uniqueness" is not merely unproven and not merely irrelevant but also utterly unhelpful for supporting forensic knowledge claims. Recall that forensic practitioners claim that uniqueness is supported by the philosophy of Leibniz. Both Kwan (1977: 14a) and Meuwly (2006: 207), in contrast, drew on a later philosopher, Wittgenstein, to argue that the very notion of uniqueness is banal. Although Wittegenstein was not specifically disputing Leibniz, in both his (otherwise very different) major works he made remarks describing uniqueness slogans as 'nonsense' (1922: §5.3304) or 'useless' (1953: § 216). Wittgenstein argued that the terms 'the same' and 'different' are meaningless unless we articulate rules for what we mean by these terms. Are two objects 'the same' or 'different'? That depends on your frame of reference. To some extent, all objects in world are 'the same' and all objects in the world are 'different' (Collins, 1985: 15).

For example, imagine yourself observing two ants. Are they the same or different? For most of us, the ants are 'identical'. It would be very difficult for us to distinguish between them, if they were displayed to us in succession. However, there may be an observer–an entomologist doing a study–for whom the ants are different. The ants, after all, are presumably not 'really' identical. In fact, presumably each ant is unique, even if discerning that uniqueness is difficult, and under sufficient magnification, one could presumably find differences between the ants in their markings, morphology, and so on. Not only might the entomologist be able to distinguish this difference, but, for her purposes, distinguishing between the ants might be essential.

What is important, then, is not uniqueness, which presumably exists for all objects relative to all other objects. Some of these unique objects may be useful for forensic identification, some not. What

matters is whether we have analytical tools necessary to discern the characteristics that *distinguish* one object from all others or, in the forensic context, distinguish *traces* made by each object from traces made by every other object. In the ant example above, errors in our detection process in which we failed to distinguish two different ants would not lead us to doubt ant uniqueness in principle or to doubt that with greater powers of magnification the two apparently 'identical' ants would be distinguishable (Jamieson, 2008: 1038). Inman and Rudin (2001) call this 'the scale of detection', which is distinguished from 'the scale of manufacture' (127). Every object is presumably unique at the scale of manufacture. The question is whether objects are distinguishable at the scale of detection. Since all objects in the universe are in some respects 'the same' and in other respects 'different' from all other objects in the universe, according to Wittgenstein, what really matters is not uniqueness but rather what rules we articulate by which we will make determinations of 'sameness' and 'difference'.

Consider now the latent print examiner's adage that all friction ridge skin is 'unique' or, put another way, 'no two areas of friction ridge skin are alike'. Since 'unique' is not defined, we can only assume that this statement means no more than that *some* difference may be found between two areas of friction ridge skin, no matter how similar. So, if you show me two very similar areas of friction ridge skin, I can find one molecule that is different between them, and I can claim that the premise of uniqueness remains intact (Risinger and Saks, 1996: 39; Kent, 2006).

What this means is that 'uniqueness' is not only unprovable and largely irrelevant to the matter of accuracy, but simply banal. To say that 'all friction ridge skin is unique' without specifying the scale of detection (as well as the area of the target, the clarity of detection, the universe of potential sources, etc.) is, as Wittgenstein (1922) put it, to say 'nothing at all' (§5.3304). We still know nothing about our ability to detect characteristics that will distinguish traces made by one source from traces made by all others. The 'uniqueness of fingerprints' is a consequence of nothing more than the definition of the term 'unique'. It is, as Champod and Evett (2001: 115) have said, 'axiomatic'.

Moreover, saying that 'all friction ridge skin is unique' does nothing to distinguish friction ridge skin from anything else in the world since, as forensic scientists say, 'all existent objects qualify as unique' (Inman and Rudin, 2001: 124; see also Houck and Siegel, 2006: 59). Whereas latent print examiners tend to believe that it is uniqueness that makes latent print analysis so powerful, in fact, uniqueness tells us nothing about why latent print analysis might be an accurate or an inaccurate forensic assay. For example, most forensic scientists would assume that latent print identification is a more discriminating forensic assay than ear, lip, or elbow print identification. Some even argue that latent print identification is valid, and ear print identification is not. Some critics of ear print identification suggest ear printing falls short because, in contrast to friction ridge skin, the 'uniqueness' of human ears has not yet been proved (Egan, n.d.; Moenssens, n.d.-a; b). However, Champod *et al.* (2001: 1275) correctly note that ears are 'unique' in precisely the same metaphysical sense that friction ridge skin (and palms, soles, lips, and elbows, and everything else in the universe) is unique. Instead, we place greater trust in latent prints than in ear printing, not because of a failure of uniqueness, but for two reasons. First, because we have less systematic data about the variability of ears within the human population than we do about friction ridge skin. Second, because the accuracy of latent print source attributions is presumably greater than that of ear print identification. The data supporting both of these claims is somewhat problematic, but most observers would probably agree with these arguments on an intuitive level. What makes one technique more useful than another is not uniqueness, which is shared by all, but rather a greater ability of some human or machine detector to make correct source attributions from one, rather than the other. This, in turn, presumably rests

on the relative degree of variability among objects that are *all* unique and the discriminating ability of the detector.[13]

Indeed, latent print examiners who have pursued the uniqueness argument to its logical end have inadvertently demonstrated its uselessness as a foundational principle. Latent print examiners contend that any area of friction ridge detail, no matter how small, is unique:

> The fact is, a single ridge is unique. Therefore, anything comprised of multiple units of something unique must also be unique. Many use the reverse argument, which is just as valid… if a whole fingerprint is unique and you cut it in half, it is still unique. There is no such thing as "half" of unique. Unique is unique (Wertheim, 2001a).[14]

This variation on Zeno's paradox may be correct, in principle, or not, but it undermines the significance of uniqueness because it proves too much. Most practitioners would agree that you (usually) cannot individualize from a single ridge. But a single ridge is unique. Therefore, uniqueness alone cannot be the basis for individualization.

It may be argued that metaphysical uniqueness was never what anyone meant when saying 'all fingerprints are unique'. Perhaps they were saying that each area of friction ridge skin is distinguishable from each other. This is undoubtedly true depending upon the scale of detection, but it is not enough to make friction ridge skin forensically useful. Because each *impression* even of the same area of friction ridge skin is unique, to support inferences of common source, areas of friction ridge skin must produce impressions that not only are distinguishable from all impressions made by all other areas of friction ridge skin but also are all associateable with one another (Risinger and Saks, 1996: 39).

Perhaps then, what is meant by 'all fingerprint are unique' is that friction ridge skin has the property that all possible impressions of each area of friction ridge skin are associateable with one another and distinguishable from all other possible impressions of all other areas of friction ridge skin. This would indeed be a useful property. Imagine if, given certain specified parameters of detection and rules for determining similarity, all impressions of each fingertip were more similar to one another than they were to any impression from any other fingertip in the universe. Of course, any such claim would need to specify the parameters of detection and posit a set of rules for determining 'consistency' such that all impressions deriving from a common source were deemed 'consistent' and all impressions deriving from different sources were deemed 'inconsistent' (Jamieson, 2008: 1037). It would be very useful if one could say of a set objects the following, which Saks and Koehler (2005) call 'the assumption of discernible uniqueness'[15]:

> [D]. Human friction ridge skin samples of [specified dimensions] are such that using [a specified detection system and specified rules for making "attributions"] all impressions derived from one sample will be accurately attributed to that sample and no impression derived from any other sample existing in the universe will be attributed to that sample.

[13] Even this account is oversimplified because we should not even think of entire disciplines being more accurate than one another. Instead, we should consider the accuracy of certain disciplines in performing certain defined tasks (Denbeaux and Risinger, 2003). For example, although latent print identification is assumed to be more accurate than ear print identification, the identification of a high-quality ear print may be more accurate than identification of some small, poor quality latent prints.

[14] Wertheim (2002: 669) has elsewhere stated "Unique multiplied by any number is also unique."

[15] The neologism has been somewhat unfairly criticized (Rudin and Inman, 2005; Harmon and Budowle, 2006). However, Rudin and Inman (2005) correctly observe the word choice was perhaps unfortunate in that it is apt to being confused with the banal notion of metaphysical uniqueness.

This says something more than metaphysical uniqueness. It says that the objects are so variable that impressions of one cannot be mistaken for any other. Assuming that the dimensions and detection system are specified, such a proposition is not banal. Unfortunately, there is no forensic assay that currently satisfies such a proposition. Indeed, such claims have been falsified for certain detection systems analysing bullet lead composition (Randich *et al.*, 2002) and latent prints (Stoney, 2001; Cole *et al.*, 2008). If this is what is meant when it is said that 'all fingerprints are unique', then it is false. It is possible to imagine sets of objects for which such propositions could be made, such as cardinal numbers (in their abstract form—not physical representations of cardinal numbers, like automobile license plates) or closed sets of objects (the friction ridge skin of the inhabitants of a lifeboat). However, such highly circumscribed sets of objects are unlikely to be widely applicable in forensic investigations.

If we set such absolute claims aside, we could reformulate proposition [D] more realistically as follows:

[E]. Human friction ridge skin samples of [specified dimensions] are such that using [a specified detection system and specified rules for making attributions] impressions derived from one sample will be attributed to that sample with [X] degree of accuracy.

The above proposition presupposes a sort of 'black-box validation' approach (Risinger *et al.*, 1998). But one could also adopt a match probability approach, resulting in a proposition such as:

[F]. Human friction ridge skin samples of [specified dimensions] are such that findings of [a specified degree of consistency] using [a specified detection system and specified conditions of analysis] between an unknown sample and a known sample reduces the potential donor pool to an estimated size of [X] within the population [Y].

Or, in Bayesian terms:

[G]. Human friction ridge skin samples of [specified dimensions] are such that findings of [a specified degree of consistency] using [a specified detection system and specified conditions of analysis] between an unknown sample and a known sample are [a specified degree of relative likelihood] if the samples derive from a common source, as opposed to a different source.

Such propositions are not banal and are empirically testable. Methods of assessing such claims, such as signal detection analysis, are well known in the biometric literature (Bolle *et al.*, 2004) and in the forensic literature as well (Phillips *et al.*, 2001). It should be noted, however, that moving forward with such propositions in forensic science does not require proving the uniqueness of the targets of analysis. Instead, what is needed is to define the parameters of analysis under which specific accuracy or rarity claims might be made. If forensic scholars can agree that this is how forensic identification techniques should be assessed, it would probably be wise to develop a term for it that avoids the word 'unique' and its derivatives altogether. To do otherwise will be to cause continued confusion among practitioners, legal actors and the lay people. For this reason, terms like Champod *et al.*'s (2004: 24) 'selectivity' (for prints) and 'expressed variability' (for marks) or Schum's (1994) 'diagnosticity' are probably preferable.

I have argued that it is not possible to speak usefully about the uniqueness of material objects without first specifying: (1) the parameters of detection, and (2) the rules governing the determination that objects are 'the same' or 'different'. A common response to this argument is that, while my point that accuracy cannot be inferred from uniqueness is taken, uniqueness cannot be *entirely*

useless. It must matter at least a little bit that friction ridge skin, e.g. is unique and not duplicative. In other words, friction ridge skin would certainly be *less* useful for forensic analysis if there *were* 'two fingerprints alike' (i.e. duplicate friction ridge skin patterns). One way of putting this is that uniqueness is necessary but not sufficient to support claims of individualization. Thus, while it may be conceded that uniqueness alone cannot support individualization, it might be argued that my argument above goes too far by granting uniqueness almost no importance at all.

While such arguments have superficial appeal, they presuppose the existence of sets of objects, which differ from areas of friction ridge skin in terms of their 'uniqueness'. But, as discussed above, no such set of objects can be identified, without specifying the parameters of detection and the rules governing the determination of 'sameness' and 'difference'. Manufactured shoe soles fresh off the assembly line, license plates, bar codes, and complete genotypes, each member of all of these sets of objects is, at least in some sense, unique. If all objects in the world are unique, then 'no two entities can be identical' (Champod *et al.*, 2001: 1275). What distinguishes areas of friction ridge skin from these other objects is not 'uniqueness'; it is their diagnosticity: our ability to assign traces of these objects to their correct source with a certain degree of specificity under certain parameters of detection and under certain rules governing such assignments.

For example, perhaps what is meant by 'there are no two fingerprint alike' is that we do not need to worry about exact duplication as a cause of misattribution. This, again, presupposes that there are sets of objects for which exact duplication *is* a cause of misattribution. For instance, some coincidental DNA matches might be thought to be caused by duplication. However, further thought makes clear that the cause of coincidental DNA matches is not exact duplication, but rather duplication under a specified set of rules for deeming attributes consistent. Were such rules not in place, a determined advocate could still find some difference in the representations even of two 'consistent' DNA profiles. That such differences are not considered significant is a property of the rules, not of DNA. It turns out that even in the case of 'unique' friction ridge skin, once rules are in place for deeming attributes consistent (i.e. if minutiae are in the same relative location, they should be considered 'consistent') there are 'coincidental matches' (Mark and Attias, 1996), *post hoc* efforts to distinguish them through finer grained analysis (i.e. 'third level detail') notwithstanding (Wertheim, 1997). In short, it is banal to talk about an absence of duplication without specifying rules for consistency because without such specification every set of objects can boast an absence of duplication. However, once rules of consistency are specified, we should expect to see some duplication, however small, in all sets of objects. The question, it would seem, is not duplication or non-duplication, but, again, diagnosticity or selectivity: some quantified assessment of the degree of duplication under a specified set of rules for determining consistency.

## 5. Critiques of individualization

If uniqueness cannot support claims of individualization, how might such claims be logically or empirically supported? Numerous forensic and evidentiary scholars have agreed that individualization—the perfect reduction of the potential donor pool of a forensic trace—to one object is not possible. These scholars have emphasized that statements about the source of a trace are always probabilistic (Stoney, 1991; Champod and Evett, 2001; Inman and Rudin, 2001: 148; Champod *et al.*, 2004: 33; Biedermann *et al.*, 2008: 128).

If this is indeed the case, how then can claims of individualization be justified? Most forensic scholars who have sought to justify claims of individualization have appealed to the 'leap of

faith' argument first articulated by Stoney (1991). Stoney contended that reaching individualization through a *subjective* process, such as fingerprinting, was possible through a 'leap of faith': the analyst becomes 'subjectively certain that the patterns could not possibly be duplicated by chance'. Many forensic scholars have echoed Stoney's claim (Inman and Rudin, 2001: 139; Champod *et al.*, 2004: 33; Meuwly, 2006: 212). Thus, until recently, even those forensic scientists who recognized that individualization was logically unsupportable tended to go along with its reformulation as a 'leap of faith'.

The persistence of the leap of faith is somewhat surprising. The language alone would seem to telegraph its unsuitability as a foundation for knowledge claims which purport to be rational or scientific. And yet, only recently have scholars begun critiquing the leap of faith. Saks and Koehler (2008: 202–205), e.g. argued that the leap of faith renders individualization unscientific. The most trenchant critique of the leap of faith has been launched by Biedermann *et al.* (2008: 122–128), who argue that 'individualization' should be conceived as a 'decision' rather than a conclusion based on data (see also Champod, 2008).

The very notion of the 'leap of faith' suggests something irrational but necessary. But if individualization is conceded to be irrational, it is not entirely clear why it is necessary. Having concluded that individualization cannot be justified on any reasonable scientific or epistemological basis, why not follow Buckleton (2005)–or, in Inman and Rudin's case, *their own* view with regard to DNA–and conclude that forensic experts ought not do it? DNA profiling has shown that non-individualizing evidence can have it both ways: convey a significant probative value *and* transparently convey information about the magnitude of the potential donor pool to fact-finders. As Biedermann *et al.* (2008) note, assuming that it is possible to make defensible probabilistic statements about trace evidence, we might reasonably ask whether individualization is 'an endeavor worth the effort '. Indeed, they suggest, properly conceived as a decision, not a proposition or a conclusion, individualization may be 'at least conceptually, needless' (130).

Obviously, 'individualizations', in some sense must occur if any criminal cases are to result in convictions. Who should make them is less obvious. Biedermann *et al.* leave open the question of who should be charged with making the decision: the expert or the finder of fact. However, given that such decision making requires balancing the relative probabilities of false positives and negatives against the relative undesirability of the consequences of each, they suggest, 'It does not seem sensible for a scientist to anticipate' the fact-finder's preferences in this regard (Biedermann *et al.*, 2008: 129). Legal doctrine is generally wary of allowing experts to make such decisions. Even if expert statements of individualization were to be permitted, such statements would have to be flagged as 'decisions' and thus clearly distinguished from statements that purport to be interpretations of data. Perhaps that clearest way to make to such a distinction apparent to the fact-finder is to charge it, not the expert, with the decision.

Remarkably little argument has been mustered as to why expert statements of individualization are necessary. Inman and Rudin (2001) simply state, 'The state of practice of forensic science is that examiners do provide opinions of individualization', hardly a ringing rationale for the practice (148). Another possibility is that forensic thinkers conceive individualization as a response to a *legal* imperative to tell the fact-finder what the evidence means. It is not a clear whence in law it is that this supposed legal imperative emanates. What legal rule requires an expert witness to turn uncertainty into certainty or to tell the jury what inference to make from their expert evidence? Forensic theorists' efforts to justify claims of individualization smacks of working backwards from a testimonial claim desired by a partisan adversary to the epistemological basis to support it.

If ‘individualization’ represents the moment at which the forensic scientist goes beyond what she knows from the data to making an inference from that data, then individualization is, simply stated, not science. In making this claim, I want to emphasize that I am not conceiving it in the way it usually is conceived. Arguments about whether or not latent print individualization is science usually concern whether latent print individualization follows ‘the scientific method’. Such debates are destined to be unproductive. There is no agreed upon scientific method followed by all practitioners of what we generally call ‘science’ (Feyerabend, 1993; Haack, 2003), and tortured attempts to argue that latent print analysis fits or does not fit some idealized version of that method (Acree, 1998; Wertheim, 2000; Triplett and Cooney, 2006) are not likely to reach resolution (Cole, 2004a).

Rather than defining ‘science’ rigidly according to some idealized ‘method’, we can use perhaps the loosest possible definition of ‘science’: any rational attempt to learn about the world (Haack, 2003). Even using this loose definition, latent print analysis is science, but the claim of individualization is not because it is a claim that its own proponents admit is not supported by data but rather is nothing more than an effort to say something legally useful. Because, as noted above, professional rules governing latent print examiners mandate that all inclusionary conclusions must be phrased as ‘individualizations’, we are left with the uneasy conclusion that latent print analysis is science, but latent print testimony *is never scientific*.

## 6. Conclusion

This article has shown that conclusions of individualization, which practitioners of some forensic identification disciplines are mandated to give and to which practitioners of other disciplines are told to aspire, cannot be supported either logically or empirically. It has shown that the uniqueness of objects of forensic analysis, the most commonly used justification for such claims, is unproven, largely irrelevant and useless for supporting such claims. It has also shown that both of the above points have been clearly made in the literature by numerous forensic scholars. And yet, it has also shown that both claims of individualization and appeals to uniqueness as support for such claims continue to be employed routinely by forensic practitioners and legal actors. Why?

One answer clearly has to lie in the perverse incentives created by the current weak legal regime that permits extremely strong claims like ‘individualization’ without empirical support (Cole, 2006a). As long as courts permit forensic expert witnesses to testify to claims like ‘individualization’, the legal actors who employ those witnesses reap the benefits of extraordinarily probative evidence. Psychological research suggests that there may be strong incentives for prosecutors to seek to have experts witnesses make the final inference of ‘individualization’ rather than leave that task to the fact-finder (Wells, 1992; McQuiston-Surrett and Saks, 2008, 2009; see also Cole, 2007). Under such a legal regime, forensic practitioners and the legal actors who employ them have a strong disincentive to change either their testimonial claims or successful rhetorical modes of supporting those claims. Developing defensible claims for non-DNA forensic identification evidence based on random match probabilities and likelihood ratios will require much hard work (to get a feel for the difficulty of this work, see Egli *et al.*, 2006; Neumann *et al.*, 2006, 2007), and the legal regime creates a disincentive for such work.

A more charitable explanation for the persistence of individualization and uniqueness is that, although forensic scholars have criticized both notions, they have not been as clear and unequivocal as they might have been. Of the many published works cited, none, except Saks and Koehler

(2008), takes as its sole focus the debunking of individualization and/or uniqueness. Moreover, as discussed above, much of the literature, though highly critical of both notions, has shied away from its own logical consequences: the end of both individualization and uniqueness as forensic concepts. It is unfortunate, e.g. that the recent NAS report, though noting that claims to individualization are unfounded for all disciplines except DNA profiling, still accepts individualization for DNA profiling and sets it as an implicit goal all for other disciplines (National Research Council, 2009: section 3, p. 2). The report also treats uniqueness as either unproven or irrelevant, but fails to acknowledge its uselessness for supporting inferences of common source (National Research Council, 2009: 1–7). This article seeks to remedy the problem by providing a sustained argument articulating the need to do away with both individualization and uniqueness as forensic concepts once and for all.

*Individualization.* Whatever may be said for even a sophisticated understanding of individualization, it seems clear that the harm caused by the concept outweighs the good. The notion of individualization creates a disincentive for research that would lead to the development of more defensible ways of framing testimonial claims about latent print inclusions. Courts' willingness to allow expert witness to offer testimony of individualization, even when that testimony consists of an inferential 'leap of faith', must surely retard the field's progress towards developing a defensible probabilistic statements about the probative value of forensic analyses. Latent print examiners who hear respected forensic scientists say individualization is justified as a leap of faith are likely to react—indeed, *have* reacted—with both anger and complacence. Anger, because they use religious terms to describe their 'science' (Specter, 2002); complacence because the underlying message is that testimonial claims of individualization are still nonetheless acceptable.

The experience of DNA profiling demonstrates that forensic science can live without individualization. Some proponents of individualization argue that fields, such as latent prints, should be exempt from the demand for data-based rarity estimates because such estimates will be more difficult to generate than they were for DNA. The argument that individualization is somehow legitimate for disciplines for which it is more difficult to generate rarity estimates is fallacious; the difference pertains to the nature of the research effort, not the nature of the evidence. More than that, the argument is perverse: its result would be that the disciplines making claims of 'individualization' are not those with data to support those claims (because data would never support such extreme claims), but rather those disciplines which in their historical development have been indifferent to both data and probabilistic thinking.

However, rather than using DNA profiling to demonstrate that one can have highly probative evidence without 'individualization' some forensic scientists have imported the notion of individualization from impression evidence into DNA profiling (Budowle 2000). This marks a step away from the relative 'transparency' (Champod and Evett, 2001) associated with DNA profiling and toward the obscurity associated with other trace evidence techniques (Buckleton, 2005). Rather than showing the non-DNA disciplines that they can thrive without 'individualization', these practitioners have *legitimated* the epistemologically bankrupt claim of 'individualization' and lent it their considerable scientific authority. As evidence of this, consider the recent letter from the IAI to the NAS, in which is claimed that it is DNA's 'business model, not the science based model, which needs to be fostered for the remaining forensic sciences' (International Association for Identification, 2007b). This would appear to be a denial of the argument that latent prints and other trace evidence disciplines need to devise ways of estimating the rarity of configurations of friction ridge details. Instead,

the IAI suggests the only thing forensic DNA profiling has to teach the other forensic disciplines is how to obtain funding.

The notion of 'individualization', which has always been a special creation of forensic science, should be discarded. Kirk's injunction that all forensic disciplines should aspire towards individualization should be replaced by an injunction to characterize the probative value of evidence with as much transparency, precision and conservatism as possible. Note the contrast between my proposed injunction and Kirk's. Whereas Kirk's injunction presupposes the evidentiary conclusion that will ultimately be presented to the jury, mine leaves the evidentiary conclusion open, to be determined by the scientific work itself.

*Uniqueness.* Let us recapitulate: uniqueness is unproven. Uniqueness cannot support claims of individualization, or otherwise contribute in any way to assessing the probative value of an association between two prints. Without further specification of what is meant by the term 'unique', any extant object, no matter how similar it may be to another object, may defensibly be termed 'unique'. Under these circumstances, it is difficult to discern any useful purpose that uniqueness serves in any forensic endeavour.

At the same time, it is not difficult to discern numerous drawbacks to the perpetuation of the notion that uniqueness is somehow important or fundamental to forensic science. It stimulates fruitless efforts to demonstrate or prove uniqueness. It diverts research efforts and resources away from useful projects like measuring the accuracy of forensic techniques and towards demonstrating the uniqueness of objects of forensic analysis (Budowle *et al*., 2006). It engages practitioners, advocates, scholars and judges in pointless debates about uniqueness, debates that are bound to be scholastic because 'uniqueness' means nothing except what you mean by it.

Finally, uniqueness misleads practitioners about the nature and the strengths and weaknesses of their own practices. Latent print examiners, e.g. appear to widely believe that the power of their technique lies in the fact in that all human friction ridge skin is unique. But, in all likelihood, that undersells the value of latent print analysis. Tool mark analysts, bite mark analysts and hair and fibre analysts make observations of unique objects. But, although measures of the accuracy of various technique are notoriously inadequate, the data we do have would suggest that latent print analysis is probably more accurate than any of these (Peterson and Markham, 1995). Therefore, the power of latent print analysis must lie elsewhere, presumably in the ability of analysts to make accurate source attributions from those unique objects or in the 'selectivity' or 'diagnosticity' of friction ridge skin.

The two concepts most frequently employed in justifying forensic identification knowledge claims are flawed. The current perception of a 'crisis' in forensic science may be attributed to many factors, but it must in part be attributed to confusion and lack of clarity about how claims of source attribution may be defensibly supported. Forensic scientists and forensic institutions should articulate a pathway to making defensible claims of source attribution that does not rest upon uniqueness and does not end in individualization. Forensic identification can live without them.

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## REFERENCES

ACREE, M.A. (1998) What Is Science? The Dilemma of Fingerprint Science Revisited. *The Print*, **14**, 4–5.

BALDING, D.J. (2005) *Weight-of-Evidence for Forensic DNA Profiles*. Wiley, Hoboken, NJ.

BIASOTTI, A. & MURDOCK, J. (2002) Firearms and Toolmark Identification: Scientific Issues. In: Faigman, D.L., Kaye, D.H., Saks, M.J., Sanders, J. (Eds.), Science in the Law: Forensic Science Issues. West, St. Paul, MN, pp. 205–230.

BIEDERMANN, A., BOZZA, S. & TARONI, F. (2008) Decision Theoretic Properties of Forensic Identification: Underlying Logic and Argumentative Implications. *Forensic Sci. Int.*, **177**, 120–132.

BOLLE, R., CONNELL, J.H., PANKANTI, S., RATHA, N.K. & SENIOR, A.W. (2004) *Guide to Biometrics*. Springer-Verlag, New York.

BOWERS, C.M. (2002) Identification from Bitemarks: Scientific Issues. In: Faigman, D.L., Kaye, D.H., Saks, M.J., Sanders, J. (Eds.), Science in the Law: Forensic Science Issues. West, St. Paul, pp. 244–293.

BRIDGES, B.C. (1946) No Duplicate Finger Prints. *Fingerprint and Identification Magazine*, **27**, 5–6.

BUCKLETON, J. (2005) Population Genetic Models. In: Buckleton, J., Triggs, C.M., Walsh, S.J. (Eds.), Forensic DNA Evidence Interpretation. CRC Press, Boca Raton, FL, pp. 65–122.

BUDOWLE, B., BUSCAGLIA, J. & PERLMAN, R.S. (2006) Review of Scientific Basis for Friction Ridge Comparisons as a Means of Identification: Committee Findings and Recommendations. *Forensic Sci. Commun.*, **8**, http://www.fbi.gov/hq/lab/fsc/backissu/jan2006/research/2006_01_research02.htm.

BUDOWLE, B., CHAKRABORTY, R., CARMODY, G. & MONSON, K.L. (2000) Source Attribution of a Forensic DNA Profile. *Forensic Science Communications*, 2, http://www.fbi.gov/hq/lab/fsc/backissu/july2000/source.htm.

CARROLL, J. (2009) Pattern Evidence Panel Discussion, Annual Meeting of the Southwestern Association of Forensic Document Examiners, Los Angeles, CA.

CHAMPOD, C. (2000) Identification/Individualization: Overview and Meaning. In: Siegel, J.A., Saukko, P.J., Knupfer, G.C. (Eds.), Encyclopedia of Forensic Sciences. Academic Press, London, pp. 1077–1083.

CHAMPOD, C. (2008) Fingerprint Examination: Towards More Transparency. *Law Probab. Risk*, **7**, 111–118.

CHAMPOD, C. & EVETT, I.W. (2001) A Probabilistic Approach to Fingerprint Evidence. *J. Forensic Identif.*, **51**, 101–122.

CHAMPOD, C., EVETT, I.W. & KUCHLER, B. (2001) Earmarks as Evidence: A Critical Review. *J. Forensic Sci.*, **46**, 1275–1284.

CHAMPOD, C., LENNARD, C., MARGOT, P. & STOILOVIC, M. (2004) *Fingerprints and Other Ridge Skin Impressions*. CRC Press, Boca Raton, FL.

COLE, S.A. (2004a) Jackson Pollack, Judge Pollak, and the Dilemma of Fingerprint Expertise. In: Edmond, G. (Ed.), Expertise in Regulation and Law. Ashgate, Aldershot, pp. 98–120.

COLE, S.A. (2004b) Grandfathering Evidence: Fingerprint Admissibility Ruling from *Jennings* to *Llera Plaza* and Back Again. *Am. Crim. L. Rev.*, **41**, 1189–1276.

COLE, S.A. (2006a) Is Fingerprint Identification Valid? Rhetorics of Reliability in Fingerprint Proponents' Discourse. *Law & Policy*, **28**, 109–135.

COLE, S.A. (2006b) 'Implicit Testing': Can Casework Validate Forensic Techniques? *Jurimetrics*, **46**, 117–128.

COLE, S.A. (2007) Where the Rubber Meets the Road: Thinking About Expert Evidence as Expert Testimony. *Villanova Law Rev.*, **52**, 803–842.

COLE, S.A., WELLING, M., DIOSO-VILLA, R. & CARPENTER, R. (2008) Beyond the Individuality of Fingerprints: A Measure of Simulated Computer Latent Print Source Attribution Accuracy. *Law Probab. Risk*, **7**, 165–189.

COLLINS, H.M. (1985) *Changing Order: Replication and Induction in Scientific Practice*. University of Chicago Press, Chicago, IL.

DENBEAUX, M. & RISINGER, D.M. (2003) *Kumho Tire* and Expert Reliability: How the Question You ask Gives the Answer You Get. *Seton Hall L. Rev.*, **34**, 15–70.

EGAN, T. n.d. Are Dutch Ears Different from American Ears?, Nov. 3. (2008), http://www.forensic-evidence.com/site/ID/ID00004_1.html.

EGLI, N., CHAMPOD, C. & MARGOT, P. (2006) Evidence Evaluation in Fingerprint Comparison and Automated Fingerprint Identification Systems – Modeling with Finger Variability. *For. Sci. Int.*, **167**, 189–195.

FAULDS, H. (1905) *Guide to Finger-Print Identification*. Wood Mitchell, Hanley.

FEYERABEND, P.K. (1993) *Against Method*. Verso, London.

GARRETT, R. (2009) Letter to All Members of the International Association for Identification, Feb. 19, available at http://www.clpex.com/Articles/TheDetail/300-399/TheDetail394.htm.

GERMAN, E. (2002) Regarding Recent News Articles on Fingerprint Evidence Credibility in Court. *Latent Print Examination: Fingerprints, Palmprints and Footprints*, http://onin.com/fp/stmt_ref_articles.html.

HAACK, S. (2003) *Defending Science – Within Reason: Between Scientism and Cynicism*. Prometheus, Amherst, NY.

HARMON, R. & BUDOWLE, B. (2006) Questions about Forensic Science. *Science*, **311**, 607.

HOUCK, M.M &, SIEGEL, J.A. (2006) *Fundamentals of Forensic Science*. Elsevier, Amsterdam.

HUBER, R.A. (1972) The Philosophy of Identification, *R.C.M.P. Gazette*, July-Aug., pp. 9–14.

HUBER, R.A. & HEADRICK, A.M. (1999) *Handwriting Identification: Facts and Fundamentals*. CRC Press, Boca Raton, FL.

IANNARELLI, A.V. (1989) *Ear Identification*. Paramount, Fremont, CA.

INMAN, K. & RUDIN, N. (2001) *Principles and Practice of Criminalistics: The Profession of Forensic Science*. CRC Press, Boca Raton, FL.

INTERNATIONAL ASSOCIATION FOR IDENTIFICATION. (2007a) IAI Position concerning Latent Fingerprint Identification. International Association for Identification, Mendota Heights, MN.

INTERNATIONAL ASSOCIATION FOR IDENTIFICATION. (2007b) Letter to National Academies Of Sciences Committee To Review The Forensic Sciences, Sept. 19, available at http://www.theiai.org/nas_letter_20070919.pdf.

JAMIESON, A. (2008) The Philosophy of Forensic Scientific Identification. *Hastings Law J.*, **59**, 1031–1046.

KASPRZAK, J. (1990) Possibilities of Cheiloscopy. *For. Sci. Int.*, **46**, 145–151.

KAYE, D.H. (2009) Identification, Individualization, Uniqueness. *Law, Probability and Risk*, in press.

KENT, T. (2006) Fingerprint Identification – Time to Move Forward. *Fingerprint Whorld*, **32**, 149–154.

KIRK, P.L. (1963) The Ontogeny of Criminalistics. *J. Crim. Law, Criminol. Police Sci.*, **54**, 235–238.

KWAN, Q.Y. (1977) Inference of Identity of Source (PhD diss), Sociology. University of California, Berkeley, Berkeley, CA.

MAIRS, G.T. (1945) Can Two Identical Ridge Patterns Actually Occur – Either on Different Person or on the Same Person?, *Fingerprint Identif Mag.*, **27**, 3–7.

MARK, Y. & ATTIAS, D. (1996) What Is the Minimum Standard of Characteristics for Fingerprint Identification? *Fingerprint Whorld*, **22**, 148–150.

MCLACHLAN, H. (1995) No Two Sets the Same? Applying Philosophy to the Theory of Fingerprints. *Philosopher*, **83**, 12–18.

MCROBERTS, A.L. (1996) Nature Never Repeats Itself, *Print,* **12**, 1–3.

MCQUISTON-SURRETT, D., SAKS, M.J. (2008) Communicating Opinion Evidence in the Forensic Identification Sciences: Accuracy and Impact. *Hastings L. J.*, **59**, 1159–1189.

MCQUISTON-SURRETT, D., SAKS, M.J. (2009) The Testimony of Forensic Identification Science: What Expert Witnesses Say and What Factfinders Hear. *Law & Human Behavior*, in press.

MEUWLY, D. (2006) Forensic Individualisation from Biometric Data. *Science & Justice*, **46**, 205–213.

MNOOKIN, J.L. (2001) Fingerprint Evidence In An Age of DNA Profiling. *Brook. L. Rev.*, **67**, 13–70.

MOENSSENS, A. (1999) Is Fingerprint Identification a "Science"? *Forensic-Evidence.com*, http://www.forensic-evidence.com/site/ID0004_2.html.

MOENSSENS, A. (2003) Fingerprint Identification: A Valid Reliable "Forensic Science"? *Crim. Just.*, **18**, 31–37.

MOENSSENS, A. (n.d.-a) Alphonse Bertillon and Ear Prints. Dec. 14, 2001, http://www.forensic-evidence.com/site/ID/ID_bertillion.html.

MOENSSENS, A. (n.d.-b) Ear Identification Research. Nov. 3, 2008, http://www.forensic-evidence.com/site/ID/ID00004_4.html.

NATIONAL RESEARCH COUNCIL. (2004) Weighing Bullet Lead Evidence. The National Academies Press, Washington, DC.

NATIONAL RESEARCH COUNCIL. (2009) Strengthening Forensic Science in the United States: A Path Forward. The National Academies, Washington DC.

NEUMANN, C., CHAMPOD, C., PUCH-SOLIS, R., EGLI, N., ANTHONIOZ, A. & BROMAGE-GRIFFITHS, A. (2007) Computation of Likelihood Ratios in Fingerprint Identification for Configurations of Any Number of Minutiae. *J. Forensic Sci.*, **52**, 54–64.

NEUMANN, C., CHAMPOD, C., PUCH-SOLIS, R., EGLI, N., ANTHONIOZ, A., MEUWLY, D. & BROMAGE-GRIFFITHS, A. (2006) Computation of Likelihood Ratios in Fingerprint Identification for Configurations of Three Minutiae. *J. Forensic Sci.*, **51**, 1–12.

NICHOLS, R. (2006) The Scientific Foundation of Firearms and Tool Mark Identification – A Response to Recent Challenges, *California Association of Criminalists News*, 2nd Quarter, pp. 8–27.

OATESS, R.T. (2000) Elbow Print Identification. *J. Forensic Identif.*, **50**, 132–137.

PANKANTI, S., PRABHAKAR, S. & JAIN, A.K. (2002) On the Individuality of Fingerprints. *IEEE Transac. PAMI*, **24**, 1010–1025.

PEOPLE V. GOMEZ (2002) No. 99CF0391 Tr. Trans. (Cal. Superior Ct. Orange Cty.).

PETERSON, J.L. & MARKHAM, P.N. (1995) Crime Laboratory Proficiency Testing Results, 1978–1991, II: Resolving Questions of Common Origin. *J. Forensic Sci.*, **40**, 1009–1029.

PHILLIPS, V.L., SAKS, M.J. & PETERSON, J.L. (2001) The Application of Signal Detection Theory to Decision-Making in Forensic Science. *J. Forensic Sci.*, **46**, 294–308.

PYREK, K.M. (2007) *Forensic Science Under Siege: The Challenges of Forensic Laboratories and the Medico-Legal Investigation System*. Academic Press, Amsterdam.

RANDICH, E., DUERFELDT, W., MCLENDON, W. & TOBIN, W. (2002) A Metallurgical Review of the Interpretation of Bullet Lead Compositional Analysis. *For. Sci. Int.*, **127**, 174–191.

RISINGER, D.M. & SAKS, M.J. (1996) Science and Nonscience in the Courts. *Iowa Law Rev.*, **82**, 21–74.

RISINGER, D.M., DENBEAUX, M. & SAKS, M.J. (1998) Brave New 'Post-Daubert World'–A Reply to Professor Moenssens. *Seton Hall Law Rev.*, **29**, 405–490.

ROBERTSON, B.W.N. (1990) Fingerprints, Relevance and Admissibility. *N. Z. Recent Law Rev.*, **2**, 252–258.

RUDIN, N. & INMAN, K. (2005) The Shifty Paradigm, Part I, *California Association of Criminalists News*, 4th quarter, pp. 13–16.

SAFERSTEIN, R. (2001) *Criminalistics: An Introduction to Forensic Science*. Prentice Hall, Upper Saddle River, NJ.

SAKS, M.J. & FAIGMAN, D.L. (2008) Failed Forensics: How Forensic Science Lost Its Way and How It Might Yet Find It. *Annu. Rev. Law. Soc. Sci.*, **4**, 149–171.

SAKS, M.J. & KOEHLER, J.J. (2005) The Coming Paradigm Shift in Forensic Identification Science. *Science*, **309**, 892–895.

SAKS, M.J. & KOEHLER, J.J. (2008) The Individualization Fallacy in Forensic Science Evidence. *Vanderbilt Law Rev.*, **61**, 199–219.

SAKS, M.J. & KOEHLER, J.J (in press). Individualization claims in forensic science. Still unwarranted. *Brooklyn Law Review*.

SAMUELS, J. (2000) Letter from National Institute of Justice Regarding the Solicitation of *Forensic Friction Ridges (Fingerprint) Examination Validation Studies*, *Forensic Science Communications*, **2,** July 2000. http://www.fbi.gov/hq/lab/fsc/backissu/july2000/nijlettr.htm.

SCHUM, D.A. (1994) *Evidential Foundations of Probabilistic Reasoning*. John Wiley & Sons, New York.

SCHWARTZ, A. (2005) A Systemic Challenge to the Reliability and Admissibility of Firearms and Toolmark Identification. *Columbia Sci. & Technol. Law Rev.*, **6**, 1–42.

SCIENTIFIC WORKING GROUP ON FRICTION RIDGE ANALYSIS STUDY AND TECHNOLOGY, (2003) Glossary - Consolidated. ver. 1.0, Sept. 9, http://www.swgfast.org/Glossary_Consolidated_ver_1.pdf.

SCIENTIFIC WORKING GROUP ON FRICTION RIDGE ANALYSIS STUDY AND TECHNOLOGY. (2004) Press Kit. July 12, 2007, http://www.swgfast.org/swgfast_press_kit_may04.html.

SPECTER, M. (2002) Do Fingerprints Lie?, *The New Yorker*, May 27, pp. 96–105.

STARRS, J.E. (1999) Judicial Control Over Scientific Supermen: Fingerprint Experts and Others Who Exceed the Bounds. *Crim. Law Bull.*, **35**, 234–276.

STATE V. HULL (2008) No. 48-CR-07-2336 (Minn. D. Ct. Cty. of Mille Lacs).

STONEY, D.A. (1991) What Made Us Ever Think We Could Individualize Using Statistics? *J. Forensic Sci. Soc.*, **31**, 197–199.

STONEY, D.A. (2001) Measurement of Fingerprint Individuality. In: Lee, H.C., Gaensslen, R.E. (Eds.), Advances in Fingerprint Technology. CRC Press, Boca Raton, FL, pp. 327–387.

STRIUPAITUS, P. (2007) Toolmark Identification, Presentation to Committee on Identifying the Needs of the Forensic Science Community, Washington, DC, http://sites.nationalacademies.org/pga/stl/forensic_science/index.htm.

SWGTREAD (2006) Standard Terminology for Expressing Conclusion of Forensic Footwear and Tire Impression Examinations. *J. Forensic Identif.*, **56**, 806–808.

TEMPLEMAN, H. (2008) A Statistical Approach to Fingerprint Identification. Nov. 2, http://www.henrytempleman.com/.

THORNTON, J.I. (1986) The Snowflake Paradigm. *J. Forensic Sci.*, **31**, 399–401.

THORNTON, J.I. & PETERSON, J.L. (2002) The General Assumptions and Rationale of Forensic Identification. In: Faigman, D.L., Kaye, D.H., Saks, M.J., Sanders, J. (Eds.), Science in the Law: Forensic Science Issues. West, St. Paul, pp. 1–45.

TRIPLETT, M. & COONEY, L. (2006) The Etiology of ACE-V and its Proper Use: An Exploration of the Relationship Between ACE-V and the Scientific Method of Hypothesis Testing. *J. Forensic Identif.*, **56**, 345–355.

TUTHILL, H. (1994) *Individualization: Principles and Procedures in Criminalistics*. Lightning Powder Company, Salem, OR.

UNITED STATES V. MERRITT, (2002) U.S. Dist. LEXIS 14711 (S.D. Ind.).

UNITED STATES V. ROGERS, (2001) 26 Fed. Appx. 171 (4th Cir.).

VANDERKOLK, J.R., (2002) Forensic Science, Psychology and Philosophy. *J. Forensic Identifi.*, **52**, 252–253.

WELLS, G.L. (1992) Naked Statistical Evidence of Liability: Is Statistical Probability Enough? *J. Pers. Soc. Psychol.*, **62**, 739–752.

WERTHEIM, K. (2001a) *The Weekly Detail*, **9**, Oct. 1, 2001. http://www.clpex.com/Articles/TheDetail/TheDetail9.htm.

WERTHEIM, K. (2001b) *The Weekly Detail*, **17**, Dec. 3, 2001. http://www.clpex.com/Articles/TheDetail/TheDetail17.htm.

WERTHEIM, K. (2002) Letter re: ACE-V: Is It Scientifically Reliable and Accurate? *J. Forensic Identif.*, **52**, 669–677.

WERTHEIM, P.A. (1997) Letter to the Editor. *Fingerprint Whorld*, **23**, 63–64.

WERTHEIM, P.A. (2000) Scientific Comparison and Identification of Fingerprint Evidence. *Print*, **16**, 1–8.

WITTGENSTEIN, L. (1922) [1951] *Tractatus Logico-Philosophicus*. Routledge & Paul, London.

WITTGENSTEIN, L. (1953) *Philosophical Investigations*. Macmillan, New York.