Individualization Using Friction Skin Impressions: Scientifically Reliable, Legally Valid

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Abstract: The adversarial structure of the American judicial system encourages critical reviews and challenges of forensic evidence. As a result, the discriminatory power of friction ridge skin impression evidence has been a prime target of debate among critics of the latent print discipline for years, the primary argument being friction ridge skin examination is neither scientifically reliable nor legally valid. Therefore, these critics advocate the exclusion of expert testimony to identifications from the legal system. This article reviews some long-held challenges to the science of friction ridge examination, which include challenges to the premise of friction ridge skin uniqueness, testimonial claims of individualization, reliability of comparative interpretations, errors and error rate data, and the legal admissibility according to Daubert standards. The flawed logic on which these challenges are based is presented along with evidence in response to the challenges regarding the scientific reliability and legal validity of the science of the examination of friction ridge skin examination.

Introduction

The adversarial structure of the American judicial system encourages critical reviews and challenges to forensic evidence proffered by opposing counsel. These challenges are welcomed and are fundamental to the constitutional rights of the accused. With the advent of new technologies and the rapid advancement of scientific knowledge and forensic application, it is no
surprise that a number of these challenges involve the reliability of forensic evidence, particularly the identification (individualization) by means of friction ridge skin (i.e., fingerprints, palmprints, footprints). The discriminatory power of friction ridge skin examinations has been well accepted within the forensic community [1–3] and judicial systems [4, 5] to offer conclusive evidence of personal identification for more than one hundred years, and thus, when presented with such powerful evidence, defendants and defense counsels alike attempt to attack the scientific premise of biological uniqueness and the reliability of the scientific interpretations of source attributions offered by expert latent print examiners in an effort to cast doubt into the minds of the court and the jury.

Although the science of friction skin examination is challenged in many areas, it is the focus of this paper to respond to some long-held challenges that attempt to reject the scientific reliability and legal validity of friction ridge skin examination. This rebuttal will be accomplished by first reviewing the arguments offered by some of the most well-known critics of the discipline and then providing arguments supporting the scientific reliability and legal validity of friction ridge skin examination as the product of extensive research in the various fields of biology, physiology, embryology, mathematics, physics, and chemistry that is well accepted by the scientific and legal communities.

**Challenging the Science of Fingerprint Identification**

There are two broadly defined challenges leveled against the science of friction ridge skin examination from which specific arguments stem:

1. Few studies exist to validate the science and its application for personal identification [6-16].

2. Friction ridge skin identification is legally admissible today only because the practice was grandfathered into the legal system when admissibility standards were, presumably, less stringent than they are today [12].
The specific arguments against the use of friction ridge skin as a means of personal identification, which stem from the broadly defined challenges listed previously, include:

1. The uniqueness of friction ridge skin has not been proven because the friction skin of everyone in the world – past and present – has not been compared [6, 7, 9, 11–16].

2. Testimonial claims of individualization are not scientifically supported because the uniqueness of friction ridge skin has not yet been proven [6, 7, 9, 12, 16].

3. The unique characteristics of friction ridge skin exist on a metaphysical level and cannot be detected for the science to be applied [6].

4. Human examiners cannot reliably interpret and discern the distinguishing characteristics of friction ridge skin from impressions to reliably apply the science [6, 8, 10].

5. Friction ridge skin examination does not satisfy the requirements set forth by Daubert which govern legal admissibility [8, 12, 13].

Evidence of Scientific Reliability and Legal Validity

*Fundamentals of Science*

Science, as defined by Merriam-Webster, is “a body of facts learned by study or experience” [17]. Every scientific pursuit begins with an observation of phenomena. This initial observation is followed by additional observations of the phenomena, creating a mass of empirical data in which the initial observation is found to always be true with no contradictory evidence. Over time, as these observations continue to accumulate en masse, the reference as a scientific law may be established. A law, as defined by Merriam-Webster [18], is “a statement of an order or relation of phenomena that so far as is known is invariable under the given conditions”. When a law has been established stating an invariable result from observations under similar conditions, hypotheses are ultimately formed as testable explanations for the occurrence of the phenomena, and formal research is undertaken to understand the reasons for the observation. Once research has revealed the underlying cause of the phenomena observed, a theory is established. A theory, as defined by Merriam-Webster [19], is “a plausible or scientifically acceptable general principle
or body of principles offered to explain phenomena”. Once a law has been established after rigorous observation and a theory has been established that explains the law through the accumulation of tested hypotheses, it is imperative that research be continuously undertaken in an effort to disprove the law or the theory. At any time, the law or the theory explaining the law may be shown to be wrong or may need to be modified if there is data to suggest so. As seen in every discipline of science, nothing in science is ever proven to the most absolute sense. However, each failed attempt to disprove the law or the theory adds additional knowledge and support for that law and theory.

**Uniqueness Premise**

The science of friction ridge skin examination, which is based on the premise that the arrangement of friction ridges are unique, and therefore can be individualized to a single source of friction skin, began as an observation more than three hundred years ago. In 1684, Dr. Nehemiah Grew, followed by G. Bidloo in 1685, began observing ridge and pore structures at a macroscopic level. Marcello Malpighi, using the newly invented microscope, studied the function and structure of friction skin at the microscopic level in 1686 [20–22]. Data from these initial observations continued to accumulate and in 1788, a common result from these observations was first stated by J. C. A. Mayer “that the arrangement of skin ridges is never duplicated in two individuals” [20]. This statement of order and relation of friction ridges has been observed since 1684 and continues to be invariably observed today.

The first systematic use of friction ridge skin for personal identification was established by Sir William Herschel in 1860. In 1880, it was suggested by Dr. Henry Faulds that fingerprints may be used for personal identification and the detection of criminals in a letter to the editor of *Nature*. By 1892, the premise of friction ridge skin uniqueness had accumulated a mass of supporting empirical data, and the first statistical test was performed by Sir Francis Galton in an effort to determine the theoretical possibility that the arrangement of friction ridges is duplicated in two individuals. As the National Academies of Science has cited, Galton estimated that the probability of two fingerprints being duplicated from two sources of friction skin was “less than the reciprocal of 40 times the world population at that time” [3].
As time progressed, additional researchers and practitioners of the science observed the variation empirically and additional probabilistic models were created, adding further support to the premise. Despite the conservative nature of these models, each of them results in probabilities much less than the reciprocal of the world’s population. These models, as reviewed by Stoney in 2001, include the Henry Model, 1900; Balthazard Model, 1911; Bose Model, 1917; Wentworth and Wilder Model, 1918; Cummins and Midlo Model, 1943; Gupta Model, 1968; Roxburgh Model, 1933; Amy Model, 1946–48; Trauring Model, 1963; Kingston Model, 1964; Osterburg Model, 1977–80; Stoney and Thornton Model, 1985–89; Champod and Margot Model, 1995–96; and Meagher, Budowle, and Ziesig Model, 1999 [23].

As technology advanced, medical researchers were able to begin understanding the underlying cause for these observations of friction ridge skin uniqueness. In 1926, Dr. Harold Cummins began researching the development of friction skin at Tulane University in Louisiana, which continued through 1946 [24]. In 1952, Dr. Alfred Hale continued Dr. Cummins’ research by looking into the role that mechanical factors during embryonic development play in regulating the morphology of friction skin [25]. As studies of friction skin morphogenesis continued, the theory was established that mechanical and physical growth forces during embryonic development are the cause for the observed uniqueness of friction skin [25]. In 1969, Mulvihill and Smith, with reference to previous work by Penrose, introduced mathematical models explaining how random mechanical growth forces influence the delineation of the individual ridges [26, 27]. These studies of embryonic development have continued through present day, most notably by Dr. William Babler [1, 28]. Over the course of the 20th century, in no single study of embryonic development was data shown to suggest the observed phenomena of friction ridge skin uniqueness as being false, which, inevitably, continually added further strength to the premise that friction ridge skin is unique [1]. This in no way, however, suggests research should not be continued in an effort to find contradictory evidence. Each failed attempt to disprove this premise adds further data in its support.

Today, and for more than a century, the science of friction ridge skin examination has been, and continues to be, empirically tested by latent print examiners all over the world for identification (and elimination). Additionally, for more than thirty years, since the advent of the automated fingerprint identification
system (AFIS), computerized comparisons have been conducted against millions of finger- and palmprints twenty-four hours a day, resulting in millions and possibly billions of comparisons. In no single instance throughout the course of the history of applying the science has empirical data been shown to disprove the uniqueness of friction ridge skin.

Individualization Testimony

Following the latter discussion of the development of the scientific premise that friction ridge skin is unique and the theory explaining the underlying causes for that uniqueness, the critics still argue that, despite the medical, mathematical, and empirical data available, friction ridge skin still has not been proven, in the most absolute sense, to be unique [6, 7, 9, 11–16]. It is argued that without proving uniqueness, in the most absolute sense, the use of friction ridge skin for personal identification and making claims of “individualization to the exclusion of all others” is unscientific and therefore not acceptable by the general scientific community [6, 7, 9, 12, 16]. However, this assumption is neither accurate nor based on any valid logic. In the late 1980s, when scientists were faced with similar questions of proving uniqueness of the human genome, it was stated by the National Research Council (NRC), formed by the National Academy of Science (NAS), which is recognized as one of the most prestigious scientific organizations and representative of the general scientific community, that:

If a sufficient set of DNA characteristics is measured, the resulting DNA profiles can be expected to be unique in all populations.... Of course it is impossible to establish uniqueness by profiling everyone in the world, but theory and experience suggests that this uniqueness is attainable in forensic typing. Indeed, some scientists would argue that the existing panoply of characteristics is already sufficient to permit unique identification in many cases. For example, it has been suggested that a probability much less than the reciprocal of the world’s population is a good indication of uniqueness. The committee has not attempted to define a specific probability that corresponds to uniqueness... but urges that research into new and cumulatively more powerful systems continue until a clear consensus emerges that DNA profiles, like dermal fingerprints, are unique. [3]
Despite the opinions of the NRC and the evidence supporting uniqueness, suggestions have been made to report examiner testimony in probabilistic terms [6, 7, 9, 29]. However, as mentioned by the NRC in 1996, the focus of attention should be on the jury’s ability to put proper weight on the conclusion without being confused with the technical jargon of that conclusion. This opinion of the NRC to focus on the ability of a jury to understand the evidence when providing examiner testimony is supported, interestingly, by Koehler, a prominent critic of testimonial claims of individualization, finding, “Previous research indicates that people struggle to understand the significance of probabilistic forensic science evidence...” [15]. In reference to expert testimony of reporting a match, the 1996 NRC states:

Scientifically valid testimony about matching DNA [or fingerprints] can take many forms. The conceivable alternatives [of presenting expert testimony would] include statements of the posterior probability that the defendant is the source of the evidence DNA, qualitative characterizations of this probability, computations of the likelihood ratio for the hypothesis that the defendant is the source, qualitative statements of this measure of the strength of the evidence... and unadorned reports of a match. Courts or legislatures must decide which of these alternatives best meets the needs of the criminal justice system. At present, policymakers must speculate about the ability of jurors to understand the significance of a match as a function of the method of presentation. Solid, empirical research into the extent to which the different methods advance juror understanding is needed. [3]

Considering the statement of the NRC in 1996, that “it is impossible to establish uniqueness by profiling everyone in the world, but theory and experience suggests that this uniqueness is attainable in forensic typing” and the urge “that research... continue until a clear consensus emerges that DNA profiles, like dermal fingerprints, are unique” [3], it can be deduced that the NRC is of the opinion that friction ridge skin uniqueness has been tested sufficiently enough for it to be considered a generally accepted natural phenomena and that it does not share the opinion of being unscientific to rely on theory and experience to suggest uniqueness. Furthermore, it is also clearly the opinion of the NRC that testimony of “qualitative statements of this measure of the strength of the evidence” and “unadorned reports of a match” are acceptable and valid forms of expert testimony [3].
Interpretation of Uniqueness

The critics continue to argue that even if uniqueness existed (noting that it has not been proven in the most absolute sense, but while making this logically invalid claim are rejecting the opinions of the general scientific community established by the NAS), we currently do not have the ability or tools to detect such uniqueness because it exists only in a metaphysical or rhetorical sense, that is, no “discernable uniqueness” [6, 8, 10]. In theory, this argument would carry some merit for discussion should the uniqueness of friction ridge skin only be observed at the cellular or molecular level; however, medical and empirical research has shown that the uniqueness of friction ridge skin pertains to the individual ridge delineation and characteristics observable at the macroscopic level [2, 30] and thus is well within the range of detection by the human observer, depending upon the quality of the impression. Latent print examiners typically rely on three levels of detail as described by Ashbaugh to quantitatively measure the clarity of the impression [30] and the ability to distinguish the unique characteristics. Level 1 detail describes the examiner’s ability to discern the overall pattern and aggregate ridge flow. Level 1 detail occurs in disproportionate amounts within the population according to statistical studies of the frequency of pattern types [31, 32]; however, individualizations cannot be effected solely on Level 1 detail because it is genetically influenced and shared by more than one individual. Level 2 detail, which is epigenetically influenced, describes the examiner’s ability to discern the individual ridge paths and ridge characteristics. And Level 3 detail, which is also epigenetically influenced, describes the examiner’s ability to discern the individual ridge unit shapes and pores. Levels 2 and 3 detail define the characteristics that are unique to friction skin, and thus individualization conclusions can be logically deduced using the information from these levels [30]. Therefore, it is the quality of the impression that dictates the examiner’s ability to detect the individual characteristics and it is the quantity of those detected characteristics, when considered according to their location, orientation, and relative spatial relationship amongst one another, that enable the use of friction ridge skin for the purpose of personal identification [30].
Errors and Error Rates

Having discussed the reliability of the science based on the uniqueness of friction ridge skin and the ability to discern that uniqueness by the human examiner, critics to the science often raise the question, Assuming that all areas of friction ridge skin are unique and assuming those unique characteristics can be detected, then why do errors exist? Their argument continues in this false logic that assuming the accuracy of those premises, then it should be assumed that the science is infallible. The argument often follows that because errors do exist, then the science must be fallible and therefore not reliable nor legally valid [8, 12, 13]. The inferences behind this latter argument do not follow standard deductive logic. The first mistake in this logic is the assumption that “because errors exist, the science is fallible”. The mistake critics often make is the confusion of the science with the application of the science. The difference between the science and the application of the science is the human factor. The potential for error exists in any endeavor undertaken by humans. The fact that errors exist does not necessarily invalidate the science or the application of that science. In fact, as stated by the NRC in 1996, “No amount of effort and improved technology can reduce the [human] error rate to zero.” But, “When errors are discovered, they are investigated thoroughly so that corrections can be made.”[3] Consider the airline industry, for example. The science behind the physics of flight is sound; however, airplanes still crash and people lose their lives. The frequency of these errors is miniscule, but the fact is that errors have occurred and will occur again at some point in the future. This unfortunate result does not mean the science is not reliable, but it does mean that at some point in the process, the practitioner of the science made an error. Through investigation, the cause of the error is determined and corrective action is taken, which might include re-training or dismissal. The science of friction ridge skin examination is no different from any other discipline where the human factor is involved. Errors have occurred in the application of the science; however, investigations have revealed that neither the science nor the methodology of that science is invalid [33]. Instead, the cause for the errors is the result of humans (insufficient training or improper application of the methodology) and corrective actions are employed. Consider, for example, the highly publicized erroneous identification of Brandon Mayfield by the Federal Bureau of Investigation (FBI). Following this erroneous identification by the FBI, critics began attacking the science.
of friction ridge skin examination as being unreliable and invalid as a means of personal identification [8, 34]. Following a thorough investigation of the incident by the United States Office of the Inspector General (OIG), it was later concluded that, among other contributing factors, the “misidentification could have been prevented through a more rigorous application of several principles of latent fingerprint identification” [33]. The incident was unfortunate, but a major contributing factor was the improper application of the science by those practitioners that resulted in the error.

Now we are left with the argument often posed by critics that, regardless of whether errors occur because of the science or because of the improper application of the science, errors do occur and will continue to occur. This leads critics to the question of error rates. How often will errors occur in the future? How often have errors occurred in the past that have gone unnoticed [8, 10, 12–15, 34, 35]? Critics argue that there is no established rate of error for the science of friction ridge skin examination and often turn to using inappropriate measures of examiner reliability such as proficiency tests [36]. However, the Collaborative Testing Services, Inc. (CTS), which is a primary provider of proficiency testing in several forensic disciplines, released its “position on the unsuitability of our [its] reported results as a source for the determination of error rates for forensic science disciplines” in a statement published in March 2010 [37]. Furthermore, according to the NRC, “Auditing and proficiency testing cannot be expected to give a meaningful estimate of the probability that a particular laboratory [or individual] has made such an error in a specific case. An unrealistically large number of proficiency tests would be needed to estimate accurately even a historical error rate.” [3] Additionally, as stated by the NRC in 1996:

Estimating rates at which nonmatching samples are declared to match from historical performance on proficiency tests is almost certain to yield wrong values. . . . The risk of error is properly considered case by case, taking into account the record of the laboratory [or examiner] performing the tests, the extent of redundancy, and the overall quality of results. However, there is no need to debate differing estimates of false match error rates when the question of a possible false match can be put to direct test. [3]
Despite opinions of the highly respected NRC, it is still often argued that, because of the lack of a statistically acceptable rate of error for the profession, it fails admissibility standards under Daubert and therefore the science of friction ridge skin examination is not reliable and should not be admissible into the courts [8, 12, 13]. The critics are failing to realize, however, that the Daubert standard applies to the methodology and not to the practitioner because error rates that are due to the application of the science are a question of the competence of the individual applying the science and not of the science itself. “Practitioner error, then, falls outside the purview of a Daubert inquiry” [36] and, therefore, is in fact admissible under the Daubert standard. The legal opinion of this issue is that methods of latent print identification could be and have been tested in the adversarial system, results have been subjected to peer review, and the chance for error was exceptionally low [38]. Furthermore, with regards to the question of whether an error occurred in a particular case, the courts find that “vigorous cross-examination, [and] presentation of contrary evidence” [39, 40] is the appropriate means of assessing that possibility, whereas the NRC similarly feels that the possibility of a false match error can be tested [3].

**Daubert Standards for Legal Admissibility**

The remaining three admissibility standards under Daubert are also often grounds for challenges and include:

1. Whether the type of evidence can be and has been tested by a scientific methodology.
2. Whether the underlying theory or technique has been subjected to peer review and has been published in professional literature.
3. Whether the method is “generally accepted” within the relevant scientific community.

Critics challenge these three remaining admissibility standards that the science of friction ridge skin examination, as well as the premise of uniqueness, has not been tested by a scientific methodology and that the underlying theory or technique has not been subjected to peer review and publication; however, as discussed in detail earlier in this paper, these arguments have no logical basis. The premise to the science of friction ridge skin examination, the natural phenomena of friction ridge skin uniqueness, has been established through a mass of empirical observation and subjected to peer review and
publication through multiple and various professional literature sources since the late 1600s. Additionally, the theory explaining the cause for this observed uniqueness has been tested using various methods both empirically and probabilistically beginning in the late 1800s. Furthermore, the science of friction ridge skin examination itself, of reliably applying the science, has been empirically demonstrated as well over the course of a century. Lastly, regarding the question of general acceptance, attempts are still made today to argue that the science of friction ridge skin examination is not generally accepted [41, 42] on the basis of the 2009 report by the NRC entitled Strengthening Forensic Science in the United States: A Path Forward [43]. These claims of lacking general acceptance are made without a basis. The science and application of the science is well accepted in the medical community, the forensic community, and the legal community. The science of friction ridge skin identification is used not only in the forensic discipline worldwide, but also in cases of identifying victims of natural disasters and in security verification systems both in government and in the private sector. Although the 2009 NRC report did indicate general areas where the forensic discipline could improve (addressing all areas of the forensic sciences) in accordance to their Congressional charge to “make recommendations for maximizing the use of forensic technologies and techniques to solve crimes, investigate deaths, and protect the public”, one of the 13 recommendations was, “Congress should authorize and appropriate funds . . . to launch a new broad-based effort to achieve nationwide fingerprint data interoperability . . . which could result in more solved crimes . . . and greater efficiency with respect to fingerprint searches.” [43] Such a recommendation by the NRC, representative of the highly respected general scientific community, is hardly one of lacking acceptance of the science of friction ridge skin examination. This statement of general acceptance is supported not only by the NRC in 2009, but also by its predecessors in 1992 and 1996. In 1992, the NRC, in its report on DNA evidence, stated, “Fingerprints were described as an individualizing characteristic as early as 1892 . . . minutiae in the fingerprint patterns, not ridge counts, are used for personal identification. The minutiae result from nongenetic events during embryonic development...” [2]. In 1996, when comparing DNA with friction ridge skin, a second NRC report states, “DNA analysis promises to be the most important tool for human identification since Francis Galton developed the use of fingerprints for that purpose. We can confidently predict that,
in the not-distant future, persons as closely related as brothers will be routinely distinguished, and DNA profiles will be as fully accepted as fingerprints now are.” [3] General acceptance is found not only in the scientific community [2, 3, 43], but it has also been found in the legal arena from 1911 until the present day [4, 5, 38, 40-42, 44-50].

Conclusion

This paper reviewed some long-held challenges to the science of friction ridge skin examination argued by some of the most well-known critics of the discipline. The primary focus of their arguments is that friction ridge skin cannot be reliably individualized to a single source to the exclusion of all others. Their arguments are supported by claims that the uniqueness of friction ridge skin has not been proven, and, if proven, is metaphysical and cannot be detected by the examiner to reliably apply the science. The critics assert that the science is not reliable and therefore is not legally valid. Furthermore, the critics attempt to exclude the application of the science of friction ridge skin examination from American courtrooms by suggesting its legal inadmissibility according to the Federal Rules of Evidence 702, which codified Daubert, that the science has not been tested and validated, has not been subjected to peer review and publication, does not have a known or predictive rate of error, and is not generally accepted by the relative scientific community.

This paper, however, demonstrates the flawed logic on which these claims rest. By arguing against the scientific reliability of friction ridge skin examination and claiming that the uniqueness of friction ridge skin has not been proven, and if proven, could not be detected, these critics are ignoring the theory and experience that have risen from the observations that occurred beginning in the late 17th century and subsequent medical research that has been performed since the early 1900s through present day. These critics are also ignoring the multiple probabilistic models that have been developed since 1892, the mass of empirical data that has accumulated since 1860 when friction ridge skin was first systematically used for the purpose of personal identification, and the billions of comparisons conducted through AFIS databases all over the world since the late 1970s and early 1980s when the AFIS technology was first introduced.

By arguing that the science of friction ridge skin examination is not legally valid and is inadmissible under the Federal Rules of Evidence 702, as codified by Daubert, the critics are failing
to take into consideration the scientific reliability established by
the mass of medical, probabilistic, and empirical data accumu-
lated over the last three hundred years in which the science
has been tested, subjected to peer review and publication, and
validated for judicial application. Additionally, the critics are
failing to take into account the blatant general acceptance of the
science by latent print examiners all over the world, as well as
the more general and highly respected scientific community, the
National Academy of Science, which is represented by multiple
research committees (NRCs) organized, in part, to review the
scientific reliability and legal validity of friction ridge skin
examination. Furthermore, the critics are ignoring the state-
ments of the NRC and multiple legal rulings in reference to
friction ridge skin uniqueness, the calculation of historical and
predictive rates of error, the root cause of the very few known
errors that have occurred in the profession throughout history,
and the validity of testimonial claims of individualization.

As this paper demonstrates, the arguments offered by these
critics are fallacious in nature and lack scientific and legal
support. It can be well agreed that the fundamental premise
of friction ridge skin uniqueness has withstood considerable
scrutiny since the late 17th century. Furthermore, considering
the most basic definition of scientific law and theory, this paper
proposes that friction ridge skin uniqueness is well within the
bounds to be considered a scientific law that will occur invari-
ably as a natural phenomenon, and it should be recognized, as
such, along with the underlying cause for this phenomenon being
theorized as the result of random mechanical growth forces
occurring during embryonic development. However, despite
the research and knowledge currently available that serve as
the foundational support for the scientific reliability and legal
validity of friction ridge skin examinations, challenges to the
science are continually welcomed and encouraged for the sake of
scientific advancement. Because nothing in science can ever be
proven in the most absolute sense, new and additional research
will always be warranted until contradictory evidence is discov-
ered. Each failed attempt to disprove the science of friction ridge
skin examination with contradictory evidence adds additional
strength and support to its established scientific reliability and
legal validity. Although research is warranted in many areas
to further advance the science, a failure to acknowledge the
information gained and foundation established to date would
be unwarranted.
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