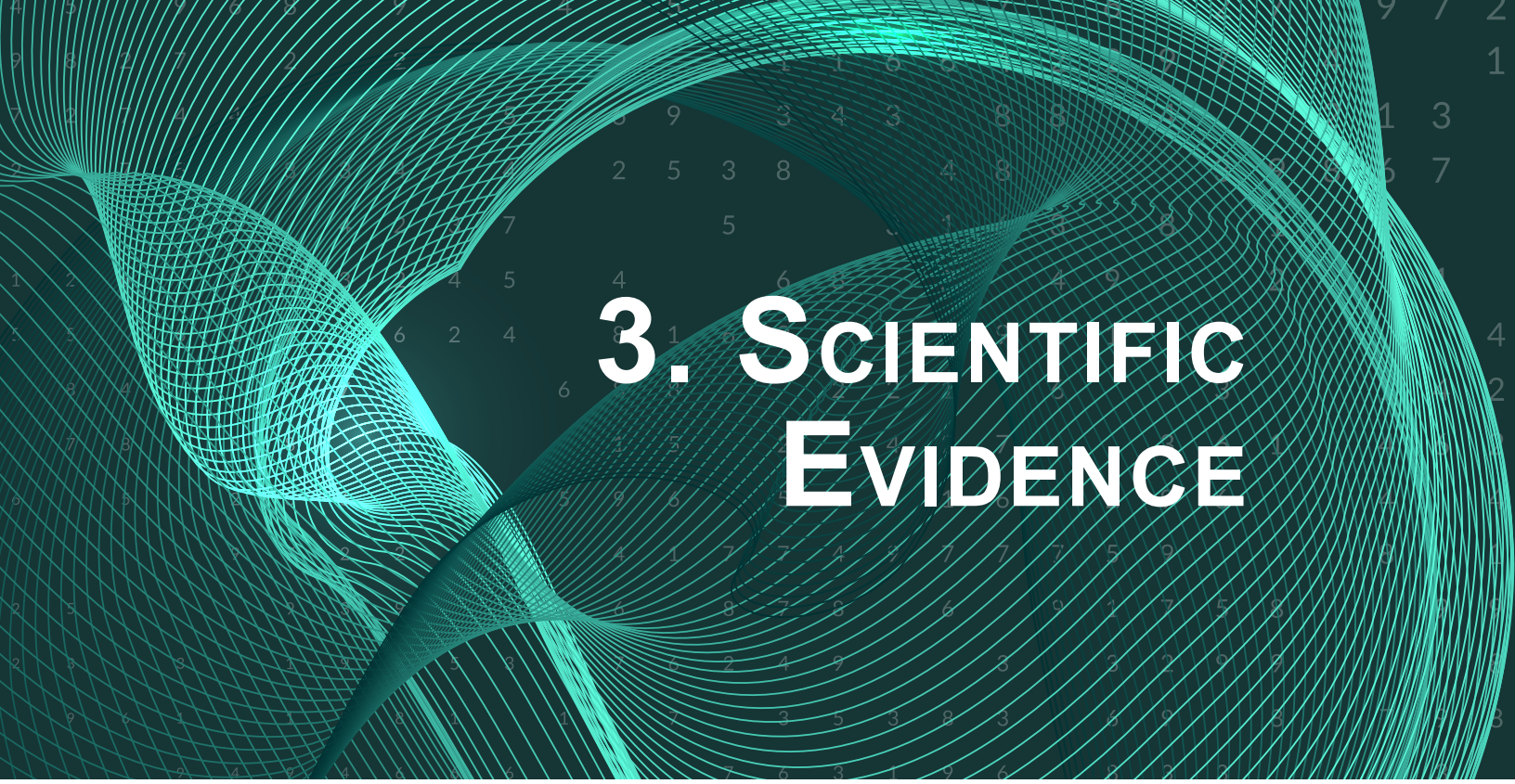

3. Scientific Evidence

Section 3.10
Forensic Pattern Evidence

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3.10.1 Introduction

Science favors neither prosecution nor defense, plaintiff nor defendant. Science, like the judiciary, is neutral. As we learn more about forensic scientific techniques and as more sophisticated research is done, assumptions we have held for years are no longer standing up to the scrutiny required by current case law. Theories continue to be tested and judges are tasked with keeping up to date on the latest knowledge. It is the job of the trial judge to decide what evidence is scientifically valid under applicable legal standards and to allow or disallow certain evidence regardless of which side is proffering it.

Science is constantly challenging itself by continuing to test hypotheses and theories. Everything is fluid. The law, by contrast, favors settled questions and is slow to move away from long held beliefs and decisions. This constant tension between law and science makes it particularly difficult for judges to decide what should come in and what should stay out of evidence.

This constant tension between law and science makes it particularly difficult for judges to decide what should come in and what should stay out of evidence.

In this section, there is an introduction about admissibility issues involving forensic pattern evidence followed by specific types of such evidence. Each specific type includes a sampling of cases and the scientific basis surrounding it. The types included are: Firearm/Tool Marks; Questioned Documents; Trace Evidence; Biological/Serology Screening; Impression Evidence; Blood Pattern Evidence; and, Shaken Baby Syndrome. In analyzing forensic pattern evidence and its use in current justice contexts, this section will examine some of the more common types of such evidence.

> Over the last two decades, advances in forensic science disciplines, especially the use of DNA technology, have demonstrated great potential to help law enforcement identify criminals. Many crimes that may have gone unsolved are now being solved because forensic science is helping to identify the perpetrators.

> Those advances, however, also have revealed that, in some cases, substantive information and testimony based on faulty forensic science analyses may have contributed to wrongful convictions of innocent people.[1]

Forensic pattern evidence encompasses a variety of techniques to associate items of physical evidence through comparison analyses to certain individuals.[2] Fingerprinting is perhaps the most well-known type of forensic pattern evidence, but others include firearm and tool marks, questioned documents including handwriting, trace evidence, biological/serology screening for hair comparison or blood typing, and impression evidence including blood pattern or spatter evidence, among others.[3]

Forensic examination follows a four-step process named ACE-V for Analysis, Comparison, Evaluation, and Verification.[4] The first three steps identified by the abbreviation ACE—analysis, comparison, and evaluation—as presented by Huber and Headrick,[5] based on the early publications by Huber.[6] The concept of conducting a sequential set of tasks distinguishing analysis from comparison goes back to the early days of forensic science. The verification step was subsequently added by forensic specialist David R. Ashbaugh[7] for fingerprint examination and adopted on most pattern comparison areas.

In recent years, there has been increasing concern about faulty forensic science. Recently the FBI acknowledged that the Bureau overstated the accuracy of hair sample matches over ninety-five percent of the time.[8] Other evidence, of patterns and impressions like bite marks and blood spatter, have been regularly used but are now being questioned.

The publication of the National Research Council *Strengthening Forensic Science in the United States* in 2009 echoed many criticisms of forensic pattern evidence and supported that with the credibility of the nation's leading scientific institution stating:[9]

> The forensic science system, encompassing both research and practice, has serious problems that can only be addressed by a national commitment to overhaul the current structure that supports the forensic science community in this country.

The concerns led to an effort to initiate a system to govern, regulate, and improve forensic science by the United States Department of Justice (DOJ) and the National Institute of Standards and Technology, as well as the National Academies, the American Association for the Advancement of Science, and the National Science Foundation.[10]

A recent development was the issuance of a memorandum by the Office Attorney General Eric Holder on September 6, 2016[11] instructing forensic scientists working in federal laboratories to no longer use the phrase "reasonable degree of scientific certainty" in court testimony. This memorandum directed forensic laboratories to review their policies and procedures to ensure that forensic examiners do not use either "reasonable degree of scientific certainty" or "reasonable degree of [forensic discipline] certainty." The DOJ based this policy change, in part, upon the idea that "scientific method" does not support the use of such language.

Since 1993, federal and most state courts have used the *Daubert* Standard (See Section 7.2.3) to determine whether scientific testimony is admissible as evidence. Under the standard, testimony can be admitted only if the expert can prove that the technique or theory used can be tested; has been peer reviewed; has a known error rate, standards and controls; and, is "generally accepted in the scientific community."[12]

Studies by the National Research Council[13] and the President's Council of Advisors on Science and Technology[14] have suggested that there is insufficient scientific research to support the claims of the broad field of "pattern matching" forensics, which includes analyses of such things as hair fiber, bite marks, "tool marks" and tire tread. These two reports question the extent of the underlying scientific research supporting these forensic specialties. The President's Council highlighted the finding in the original National Research Council report:[15]

> [M]uch forensic evidence—including, for example, bitemarks and firearm and toolmark identifications—is introduced in criminal trials without any meaningful scientific validation, determination of error rates, or reliability testing to explain the limits of the discipline.

As Betty Layne DesPortes, J.D., M.S., former president of the American Academy of Forensic Sciences, in an interview with Science Friday concluded:[16]

> Law enforcement has relied on these disciplines for so long, and they believe in them. It's very difficult for them to appreciate the fact that, because they did not arise in science—like DNA and some of the other chemistry disciplines did—that these techniques lack some of the validation studies necessary to prove their worth and their reliability.

3.10.2 Firearms/Tool Marks

Admissibility

The decision to allow such evidence is part of the court's gatekeeping function as applied to expert testimony. Questions concerning subjective vs. objective method of analysis is the main concern. Various courts have addressed the admission of firearm tool mark evidence, and almost always have allowed the admission of such evidence. The caveat appears to be how the analyst is allowed to frame their expert opinion: whether as an "identification," an "elimination" or simply as a "degree of certainty" that the marks in question were made by "particular" or "specific" firearm or a "similar" one and whether that opinion is required to be enunciated as being to "a reasonable degree of scientific certainty," now a disfavored phrase.

Description/Explanation of the Science

As explained in the Report To The President *Forensic Science In Criminal Courts*:[17] Ensuring Scientific Validity Of Feature-Comparison Methods, Executive Office Of The President, presented by the President's Council Of Advisors On Science And Technology in September 2016, firearms analysis attempts to determine whether ammunition is or is not associated with a specific firearm based on tool marks produced by guns on the ammunition.[18] This is based upon a determination that gun barrels are typically rifled to improve accuracy (i.e., spiral grooves are cut into the barrel's interior to impart spin on the bullet). Examiners work to determine whether imperfections produced during the tool-cutting process and through "wear" through the use of the firearm leave individualized marks on bullets or casings as they exit

the firearm.[19] For example, analysts compare cartridge cases recovered from a crime scene to a gun recovered at that scene or from a suspected perpetrator.

> Much attention in this scientific discipline has focused on trying to prove the notion that every gun produces 'unique' tool marks. In 2004, the NIJ [National Institute of Justice] asked the NRC [National Research Council] to study the feasibility, accuracy, reliability, and advisability of developing a comprehensive national ballistics database of images from bullets fired from all, or nearly all, newly manufactured or imported guns for the purpose of matching ballistics from a crime scene to a gun and information on its initial owner.
>
> In its 2008 report, a NRC committee, responding to NIJ's request, found that the validity of the fundamental assumptions of uniqueness and reproducibility of firearms-related toolmarks had not yet been demonstrated and that, given current comparison methods, a database search would likely 'return too large a subset of candidate matches to be practically useful for investigative purposes.'[20, 21]

While "matching" a cartridge to a particular gun is a goal, it is not the only evidentiary use of such tool marks.[22] But, it is essential that an expert proposing such evidence provide the accuracy of the method for comparing them in testimony.[23]

In its 2009 study, the NRC reviewed firearm/tool mark analysis, with the following conclusions.

> Tool mark and firearms analysis suffers from the same limitations . . . for impression evidence. Because not enough is known about the variabilities among individual tools and guns, we are not able to specify how many points of similarity are necessary for a given level of confidence in the result. Sufficient studies have not been done to understand the reliability and repeatability of the methods. The committee agrees that class characteristics are helpful in narrowing the pool of tools that may have left a distinctive mark. Individual

> patterns from manufacture or from wear might, in some cases, be distinctive enough to suggest one particular source, but additional studies should be performed to make the process of individualization more precise and repeatable.
>
> A fundamental problem with tool mark and firearms analysis is the lack of a precisely defined process . . . . [The Association of Firearm and Tool Mark Examiners] (AFTE) has adopted a theory of identification, but it does not provide a specific protocol. It says that an examiner may offer an opinion that a specific tool or firearm was the source of a specific set of tool marks or a bullet striation pattern when 'sufficient agreement' exists in the pattern of two sets of marks. It defines agreement as significant 'when it exceeds the best agreement demonstrated between tool marks known to have been produced by different tools and is consistent with the agreement demonstrated by tool marks known to have been produced by the same tool.' The meaning of 'exceeds the best agreement' and 'consistent with' are not specified, and the examiner is expected to draw on his or her own experience. This AFTE document, which is the best guidance available for the field of tool mark identification, does not even consider, let alone address, questions regarding variability, reliability, repeatability, or the number of correlations needed to achieve a given degree of confidence.[24]

A 2014 NIJ study, described in a journal article –"Study Identifies Ways to Improve ATF Ballistic Evidence Program"—looked at the operation of the National Integrated Ballistic Information Network (NIBIN), not at the underlying science of firearm and tool mark examination.[25] This forensic science—sometimes referred to by laypeople as "ballistics"—is concerned with the validity of matching a fired bullet to a particular firearm.[26] The study specifically looked at the current state of the science of firearm and tool mark examinations and whether they are accurate, reliable and valid.[27] The study—a collaboration between a Florida International University statistician and the Miami-Dade Police Department (which has been studying Glock barrels since 1994)—found that the examiners correctly matched the spent bullet to the barrel that fired it 98.8 percent of the time.[28]

The scientific criteria for foundational validity require appropriately designed studies by more than one group to ensure reproducibility.[29] In order to validate ballistic tool mark evidence,[30] there is a need for additional, appropriately designed black-box studies.[31]

In addition to tool mark analysis, past courts have allowed testimony regarding "Comparative Bullet Lead Analysis" (CBLA) based upon [the Federal Bureau of Investigation] (FBI) comparisons.[32] This type of analyses occurred when a bullet was recovered from a crime scene and the bullet was too deformed for an expert to compare its striations to those on bullets fired from the defendant's weapon. The FBI previously resorted to CBLA, analyzing seven elements in the crime scene bullet and bullets recovered from the defendant's possession.[33] An expert often relied on CBLA as a basis for opining that the bullets came from the same batch (a single day's manufacturing production) or the same box recovered from the defendant.[34] But CBLA critics pointed out that even the limited testimony about a batch is valid only if each batch is unique and uniform.[35] Later analyses of bullet-manufacturer data indicated that neither assumption was true.[36] A 2004 National Research Council report endorsed that criticism, and the FBI discontinued the use of CBLA.[37]

3.10.3 Questioned Documents (Including Handwriting, Ink, Ink Marks)

Admissibility

Courts are split about the admissibility of forensic examination of documents expert testimony.[38]

Description/Explanation of the Science

Questioned document examination involves comparison of documents and printing and writing instruments in order to identify or eliminate persons as the source of the handwriting; to reveal alterations, additions, or deletions; or to identify or eliminate the source of typewriting or other impression marks. Questions about documents

arise in business, finance, and civil and criminal trials, and in any matter affected by the integrity of written communications and records. Typical analyses include:

- determining whether the document is the output of mechanical or electronic imaging devices such as printers, copying machines, and facsimile equipment;
- identifying or eliminating particular human or machine sources of handwriting, printing, or typewriting;
- identifying or eliminating ink, paper, and writing instrument;
- establishing the source, history, sequence of preparation, alterations or additions to documents, and relationships of documents;
- deciphering and restoring obscured, deleted, or damaged parts of documents;
- recognizing and preserving other physical evidence that may be present in documents; and
- determining the age of a document.[39]

Questioned document examiners are also referred to as forensic document examiners or handwriting experts; questioned document examination includes the field of handwriting identification, while handwriting includes cursive or script style writing, printing by hand, signatures, numerals, or other written marks or signs. Forensic document examination does not involve a study of handwriting that purports to create a personality profile or otherwise analyze or judge the writer's personality or character.[40]

The validity of handwriting analysis has improved through recent empirical studies of the individuality and consistency of handwriting and computer studies which suggests that there may be a scientific basis for handwriting comparison, at least in the absence of intentional obfuscation or forgery.[41] Because of this increased study and based upon the proven reliability and replicability of the practices used by trained document examiners, the NRC found there to be "some value in handwriting analysis."[42]

The extensive scrutiny of the methods and findings of numerous areas of expert testimony following the *Daubert* trilogy has prompted acrimonious debate among academicians, forensic practitioners, and legal professionals concerning what has been referred to by the Forensic Science Committee of the National Academy of Sciences as 'faulty forensic science analyses.' The field of forensic document examination consists of a wide array of specialized tasks related to the history and preparation of questioned documents. Forensic document examiners (FDEs) identify the source of handwriting and hand printing, distinguish among genuine, forged, traced, or disguised writing; to analyze inks, papers, and other substances related to documents, and perform other scientific or technical analyses requiring highly specialized skills. Handwriting analysis is based on the premise that handwriting is based on physiological and neurological foundations. Handwriting is a behavioral artifact, identifiable by the presence of features and characteristics within the writing (e.g., signatures, hand printing, numerals). The combination of these features individualizes the habit pattern of the writer. Thus, the two primary tenets of handwriting analysis are: (1) no two people write exactly alike in all features and characteristics when considered cumulatively and in combination (inter-writer variation); and (2) a person does not write exactly the same way twice (intra-writer variation). One important issue which has not been adequately resolved by extant research is information about the validity of forensic document examination.[43]

3.10.4 Trace Evidence

Admissibility

The question of admissibility for trace evidence hinges on the type of evidence offered to be admitted. While soil samples or matching certain types of materials have been admitted (although testimony is most often limited to being "similar" in nature or "having the presence" of a certain chemical or compound), other evidence has been excluded such as comparative analysis of bullet lead or "identical" nature of two samples of a material or compound including gasoline or insulation.[44]

Description/Explanation of the Science

> Trace evidence is commonly defined at the conceptual level as follows:
>
> — the surviving evidence of a former occurrence or action of some event or agent; and
>
> — a very small amount of substance, often too small to be measured.
>
> At a more practical level, trace evidence is defined as the analysis of materials that, because of their size or texture, transfer from one location to another and persist there for some period of time. Microscopy, either directly or as an adjunct to another instrument, is involved. In this context size matters; typical examples of trace evidence include fibers, hairs, glass fragments, paint chips, soil, botanical traces, gunshot residues, etc.[45]

With the advances in forensic science, there has been growing acceptance of trace evidence where such evidence points to more basic material or physical information on a suspected crime. At the same time, the absence of trace evidence or the presence of trace evidence that contradicts or does not agree with the theory of the crime may have just as much significance in considering the case being investigated.[46]

Trace evidence did not get a lot of analysis in the NAS report, other than criticisms regarding areas of testing such as microscopic hair examination.[47] Trace evidence analysis relies upon on science that has been used by experts outside of the criminal justice arena, and thus has enjoyed more independent confirmation.[48] In making an evidentiary determination courts should consider the nature of the testimony and the qualifications of the presented expert to determine whether their level of experience and adherence to accepted scientific principles was used to interpret analytical results.

3.10.5 Biological/Serology Screening (Hair, Fingernails, Blood Type, Etc.)

3.10.5.1 Serology

Admissibility

When evaluating forensic tests on suspected blood, semen, or saliva evidence, it is important to understand the difference between presumptive and confirmatory tests and why that distinction is so important.

Presumptive Tests are also known as preliminary tests, screening tests or field tests. Presumptive tests are used to establish the possibility that a specific bodily fluid is present, but they do not conclusively prove the presence of a specific substance. **Pros**: Narrows possibilities, can be used on larger areas, and can locate possible evidence not visible to naked eye. **Cons**: Risk of false positives and may be overly sensitive. **Uses**: Provide initial information to determine what test to perform next, used in combination with confirmatory tests.

Confirmatory Tests—Conclusively identify a biological material. May be one or a combination of procedures. **Pros**: Conclusively identifies a substance, smaller risk of false positives. **Cons**: May be more expensive, require additional equipment, and take longer.[49]

Description/Explanation of the Science

Biological evidence is provided by specimens . . . that are available in a forensic investigation. Such specimens may be found at the scene of a crime or on a person, clothing, or weapon. Some—for example, pet hairs, insects, seeds, or other botanical remnants—come from the crime scene or from an environment through which a victim or suspect has recently traversed.[50] Other biological evidence comes from

specimens obtained directly from the victim or suspect, such as blood, semen, saliva, vaginal secretions, sweat, epithelial cells, vomitus, feces, urine, hair, tissue, bones, and microbiological and viral agents.[51] The most common types of biological evidence collected for examination are blood, semen, and saliva. Human biological evidence that contains nuclear DNA can be particularly valuable because the possibility exists to associate that evidence with one individual with a degree of reliability that is acceptable for criminal justice.[52]

3.10.5.2 Hair analysis

Admissibility

The question of admissibility of expert testimony regarding hair comparison analysis or testing of hair samples has changed significantly in recent years as noted by University of California Davis School of Law Professor Edward Imwinkelried in an analysis of forensic evidence:

> In an FBI study of 268 microscopic hair analysis cases, reviewers found that prosecution experts had overstated at 96% of the trials. Another FBI study compared microscopic hair analysis opinions with [mitochrondrial DNA] (mtDNA) test results. In 11% of the cases in which the analysts opined that the defendant was a possible source of the two 'microscopically indistinguishable' hair samples, the DNA established that the defendant was not the source. In 2016, a Massachusetts Superior Court granted a new trial because the mtDNA research had gravely undermined confidence in microscopic hair analysis.[53]

The key question appears to be not whether experts in hair comparison analysis can testify—as almost all courts allow such testimony—but the way their conclusions are stated. It appears that most courts do not limit such testimony based upon most recent FBI guidelines, which provide for stating that samples are "consistent with" or "similar to" each other and not identical or unequivocally from the same person.[54]

Description/Explanation of the Science

The basis for the forensic use of hair comparison analyses starts from the fact that humans shed hair constantly and so may be picked up or transferred to another individual at a crime scene. Forensic hair examiners look for various physical characteristics which can be identified as coming from a particular group of people or even a particular person based on some unique characteristics.[55] Testimony should be allowed only to the effect that the sample could have come from a person in question, but not that it is unique to a single individual.[56] Most often this information can be used to include or exclude a person from a group that could have contributed the hair being analyzed. But care must be taken in such analysis because human hairs from different parts of the body are likely to have very different characteristics.[57, 58]

Testimony linking microscopic hair analysis with particular defendants is highly unreliable. Microscopic studies alone are of limited probative value.

As stated in *Strengthening Forensic Science* noted above,

> [N]o scientifically accepted statistics exist about the frequency with which particular characteristics of hair are distributed in the population. There appear to be no uniform standards on the number of features on which hairs must agree before an examiner may declare a "match." In one study of validity and accuracy of the technique, the authors required exact agreement on seven 'major' characteristics and at least two agreements among six 'secondary' characteristics. Further evaluation of probabilities in human hair comparisons. The categorization of hair features depends heavily on examiner proficiency and practical experience. An FBI study found that, of 80 hair comparisons that were 'associated' through microscopic examinations, 9 of them (12.5 percent) were found in fact to come from different sources when reexamined through mtDNA analysis. This illustrates not only the imprecision of microscopic hair analyses, but also the problem with using imprecise reporting terminology

> such as 'associated with,' which is not clearly defined, and which can be misunderstood to imply individualization. In some recent cases, courts have explicitly stated that microscopic hair analysis is a technique generally accepted in the scientific community. But courts also have recognized that testimony linking microscopic hair analysis with particular defendants is highly unreliable. . . . In cases where there seems to be a morphological match (based on microscopic examination), it must be confirmed using mtDNA analysis; microscopic studies alone are of limited probative value. The [Committee on Identifying the Needs of the Forensic Science Community] found no scientific support for the use of hair comparisons for individualization in the absence of nuclear DNA. Microscopy and mtDNA analysis can be used in tandem and may add to one another's value for classifying a common source, but no studies have been performed specifically to quantify the reliability of their joint use. [internal citations omitted][59]

Similarly, the President's Council of Advisors on Science and Technology (PCAST) analyzed forensic hair comparisons in its 2016 Report to The President *Forensic Science In Criminal Courts* noted above.[60] There, it found noted that it had reviewed the DOJ's comment guidelines concerning testimony on hair examination that included supporting documents addressing the validity and reliability of the discipline. [61] The PCAST report expressed its concern in how the DOJ had addressed a 2002 FBI study on hair examination. In that 2002 study, FBI personnel used mtDNA analysis to re-examine 170 samples from previous cases in which the FBI Laboratory had performed microscopic hair examination.[62] The authors found that, in 9 of 80 cases (11 percent) in which the FBI Laboratory had found the hairs to be microscopically indistinguishable, the DNA analysis showed that the hairs actually came from *different* individuals.

> The 2002 FBI study is a landmark in forensic science because it was the first study to systematically and comprehensively analyze a large collection of previous casework to measure the frequency of false-positive associations. Its conclusion is of enormous importance to forensic science, to police, to courts and to juries: *When hair examiners conclude in casework that two hair samples are*

microscopically indistinguishable, the hairs often (1 in 9 times) come from different sources.[63]

As the PCAST report concluded,

> Our brief review is intended simply to illustrate potential pitfalls in evaluations of the foundational validity and reliability of a method. PCAST is mindful of the constraints that DOJ faces in undertaking scientific evaluations of the validity and reliability of forensic methods, because critical evaluations by DOJ might be taken as admissions that could be used to challenge past convictions or current prosecutions.
>
> These issues highlight why it is important for evaluations of scientific validity and reliability to be carried out by a science-based agency that is not itself involved in the application of forensic science within the legal system . . . .
>
> They also underscore why it is important that quantitative information about the reliability of methods (e.g., the frequency of false associations in hair analysis) be stated clearly in expert testimony . . . . DOJ's proposed guidelines . . . would bar examiners from providing information about the statistical weight or probability of a conclusion that a questioned hair comes from a particular source.
>
> . . . [M]any forensic feature-comparison methods have historically been assumed rather than *established* to be foundationally valid based on appropriate empirical evidence. Only within the past decade has the forensic science community begun to recognize the need to empirically test whether specific methods meet the scientific criteria for scientific validity. Only in the past five years, for example, have there been appropriate studies that establish the foundational validity and measure the reliability of latent fingerprint analysis. For most subjective methods, there are no appropriate black-box studies with the result that there is no appropriate evidence of foundational validity or estimates of reliability.[64]

3.10.6 Impression Evidence

Impression evidence is created when an object leaves behind an indentation or mark. Impression evidence can be two-dimensional, like a fingerprint, or three-dimensional—like footwear imprints. This subsection will examine several types of impression evidence including fingerprints, footwear, tire marks and bite marks.

The general approach concerning the analytical sequence of various types of impression evidence, is based upon the concept that each has its own set of characteristics. For example, some types of impression evidence, such as those arising from footwear and tires, require knowledge of manufacturing and wear, while other types, such as ear prints and bloodstain patterns, do not. Because footwear and tire track impressions comprise the bulk of the examinations conducted, the remarks in this section are specifically focused on these analyses.

Experts in impression evidence argue that they accumulate a sense of those probabilities through experience, which may be true. However, it is difficult to avoid biases in experience-based judgments, especially in the absence of a feedback mechanism to correct an erroneous judgment.[65] These problems are exacerbated with the less common types of impression evidence. For example, a European survey found that 42 laboratories conducted 28,093 shoeprint examinations and 41 laboratories conducted 591 tire track examinations, but only 14 laboratories conducted a total of 21 lip print examinations and 17 laboratories conducted a total of 100 ear print examinations.

Part of the justification for the admission of impression evidence is that those who perform the work in laboratories that conduct hundreds or thousands of evaluations of impression evidence develop useful experience and judgment, however, there is still a lack of scientific data about the natural variability of those less frequent impressions, absent the presence of a clear deformity or scar, to infer whether the observed degree of similarity is significant. Most of the research in the field is conducted in forensic laboratories, with the results published in trade journals such as the *Journal of Forensic Identification*. The Scientific Working Group for Shoeprint and Tire Tread Evidence (SWGTREAD) is moving toward the use of standard language to convey the conclusions reached. But neither the International Association for Identification (IAI) nor SWGTREAD addresses the issue of

what critical research should be done or by whom; critical questions that should be addressed include the persistence of individual characteristics, the rarity of certain characteristic types, and the appropriate statistical standards to apply to the significance of individual characteristics. Also, little if any research has been done to address rare impression evidence. Much more research on these matters is needed.

3.10.6.1 Footwear

ADMISSIBILITY

Courts have generally allowed footwear impression evidence. The limitations on the admission is similar to tool mark evidence where the expert is allowed to frame their opinion into general classification of similarity, rather than to a specific shoe identification.

DESCRIPTION/EXPLANATION OF THE SCIENCE

Footwear analysis is a process that typically involves comparing a known object, such as a shoe, to a complete or partial impression found at a crime scene, to assess whether the object is likely to be the source of the impression. The process proceeds in a stepwise manner, beginning with a comparison of 'class characteristics' (such as design, physical size, and general wear) and then moving to 'identifying characteristics' or 'randomly acquired characteristics (RACs)' such as marks on a shoe caused by cuts, nicks, and gouges in the course of use.[66]

There are no appropriate empirical studies to support the association of shoeprints with particular shoes based on specific identifying marks.

PCAST focused on the reliability of conclusions, based on RACs, that an impression was likely to have come from a specific piece of footwear. This is a much harder problem, because it requires knowing

> how accurately examiners identify specific features shared between a shoe and an impression; how often they fail to identify features that would distinguish them; and, what probative value should be ascribed to a particular RAC[67]
>
> The absence of empirical studies that measure examiners' accuracy, was cited in the NRC report casting doubt on whether footwear examiners reach consistent conclusions when presented with the same evidence.[68]

The PCAST report reached the following conclusion: "… [T]he fundamental issue is not one of *consistency* (whether examiners give the *same* answer) but rather of *accuracy* (whether they give the *right* answer).[69]

> PCAST finds there are no appropriate empirical studies to support the foundational validity of footwear analysis to associate shoeprints with particular shoes based on specific identifying marks (sometimes called "randomly acquired characteristics"). Such conclusions are unsupported by any meaningful evidence or estimates of their accuracy and thus are not scientifically valid.[70]

3.10.6.2 Tire Impressions, etc.

Admissibility

Courts have generally allowed footwear impression evidence. The limitations to the admission is similar to tool mark evidence where the expert is allowed to frame their opinion into general classification of similarity, rather than to a specific shoe identification.

Description/Explanation of the Science

> The scientific basis for the evaluation of impression evidence is that mass-produced items pick up features of wear that, over time, individualize them.[71] However, because these features continue

to change as they are worn . . . or used, elapsed time after a crime can undercut the forensic scientist's certainty. At the least, class characteristics can be identified, and with sufficiently distinctive patterns of wear, one might hope for specific individualization. However, there is no consensus regarding the number of individual characteristics needed to make a positive identification, and the Committee on Identifying Needs of the Forensic Sciences Community, [NRC] is not aware of any data about the variability of class or individual characteristics or about the validity or reliability of the method.[72] Without such population studies, it is impossible to assess the number of characteristics that must match in order to have any particular degree of confidence about the source of the impression.[73]

3.10.6.3 Bite Marks

ADMISSIBILITY

The history of bite mark evidence is an example of the need for a better judicial understanding regarding the admissibility of scientific evidence.[74] California was the first state in 1975 to allow the admission of bite mark expert testimony in the case *People v. Marx*.[75] Three dentists claimed that they could match bite marks on the victim's nose to the teeth of the defendant.[76] California followed a federal guideline that allowed the defendant to challenge the scientific validity of scientific testimony, but the appeals court ruled that bite mark matching was less science than a matter of common sense.[77] Three years later, another California appeals court cited *Marx* in upholding bite mark testimony once again, noting the "superior trustworthiness of the scientific bite mark approach." But the *Marx* judges had explicitly noted that the analysis *wasn't* scientific. Nonetheless, other courts began citing the case. By 1987, 21 state appellate courts across the United States had accepted bite mark analysis, without a single

Bite mark "evidence" has led to more than two dozen wrongful arrests and convictions.

dissenting opinion. By 2004, courts in 37 U.S. jurisdictions had accepted it.[78]

Description/Explanation of the Science

In its study, the NRC noted that "[a]lthough the identification of human remains by their dental characteristics is well established in the forensic science disciplines, there is continuing dispute over the value and scientific validity of comparing and identifying bite marks."[79,80]

Despite the inherent weaknesses involved in bite mark comparison, it is reasonable to assume that the process can sometimes reliably exclude suspects. Although the methods of collection of bite mark evidence are relatively noncontroversial, there is considerable dispute about the value and reliability of the collected data for interpretation. Some of the key areas of dispute include the accuracy of human skin as a reliable registration material for bite marks, the uniqueness of human dentition, the techniques used for analysis, and the role of examiner bias . . . . The [American Board of Forensic Odontology] (ABFO) has developed guidelines for the analysis of bite marks to standardize analysis,[81] but there is still no general agreement among practicing forensic odontologists about national or international standards for comparison.

> *"[There is] no evidence of an existing scientific basis for identifying an individual [using bite marks] to the exclusion of all others.*

Although the majority of forensic odontologists are satisfied that bite marks can demonstrate sufficient detail for positive identification,[82] no scientific studies support this assessment, and no large population studies have been conducted. In numerous instances, experts diverge widely in their evaluations of the same bite mark evidence,[83] which has led to questioning of the value and scientific objectivity of such evidence.

> Bite mark testimony has been criticized as lacking an existing scientific basis for identifying an individual to the exclusion of all others. That same finding was reported in a 2001 review, which "revealed a lack of valid evidence to support many of the assumptions made by forensic dentists during bite mark comparisons."[84] Some research is warranted in order to identify the circumstances within which the methods of forensic odontology can provide probative value.[85]

Additionally, the NIJ noted:

> The forensic methods that are most frequently associated with wrongful conviction cases are forensic serology (e.g., ABO blood typing and secretor status), microscopic hair analysis, and bite marks. However, the last case involving any of these three disciplines was in the late 1990s . . . . Over the years, the . . . ABFO has changed its guidance for associating bite mark impressions. In a December 2000 document,[86] the ABFO issued the following guidance: The term reasonable medical certainty conveys the connotation of virtual certainty or beyond reasonable doubt. The term deliberately avoids the message of unconditional certainty only in deference to the scientific maxim that one can never be absolutely positive unless everyone in the world was examined or the expert was an eye witness. The Board considers that a statement of absolute certainty such as "indeed, without a doubt," is unprovable and reckless. Reasonable medical certainty represents the highest order of confidence in a comparison. It is, however, acceptable to state that there is "no doubt in my mind" or "in my opinion, the suspect is the biter" when such statements are prompted in testimony. In its most recent guidance (2016), the ABFO states that '[t]erms assuring unconditional identification of a perpetrator, or identification 'without doubt,' are not sanctioned as final conclusions in an open population case.'[87,88]

And, as the NRC noted, "There is continuing dispute over the value and scientific validity of comparing and identifying bite marks."[89]

3.10.6.4 Fingerprints

Admissibility

Courts have generally allowed fingerprint evidence.

Description/Explanation of the Science

> Fingerprint identification is based upon these premises: that the basic characteristics of fingerprints do not change with time, and that fingerprints are unique to an individual.[90] The validity of perfection has been established. The uniqueness of fingerprints has been accepted over time because of lack of contradiction and relentless repetition.
>
> Collectively, the analysis of these prints is known as 'friction ridge analysis,' which consists of experience-based comparisons of the impressions left by the ridge structures of volar (hands and feet) surfaces.[91] Friction ridge analysis is an example of what the forensic science community uses as a method for assessing 'individualization'—the conclusion that a piece of evidence (here, a pattern left by friction ridges) comes from a single unambiguous source.[92] Friction ridge analysis shares similarities with other experience-based methods of pattern recognition, such as those for footwear and tire impressions, tool marks, and handwriting analysis . . . .[93]
>
> But the basic assumption that everyone has a unique fingerprint from which they can be quickly identified through a computer database is flawed, experts have claimed.[94] Despite the widely held belief that fingerprint analysis is accurate, there are others that think 'The time is ripe for the traditional forensic sciences to replace antiquated assumptions of uniqueness and perfection with more defensible empirical and probabilistic foundation.'[95]

Historically, friction ridge analysis has served as a valuable tool, both to identify the guilty and to exclude the innocent. Because of the amount of detail available in friction ridges, it seems plausible that a careful comparison of two impressions can accurately discern whether or not they had a common source.[96] Although there is limited information about the accuracy and reliability of friction ridge analyses, claims that these analyses have zero error rates are not scientifically plausible.[97]

3.10.7 Blood Pattern Evidence (aka Blood Spatter)

ADMISSIBILITY

The Texas Forensic Science Commission, a national leader in forensic science reform, has stated that the blood-spatter analysis used to convict a former Texas high school principal of murdering his wife in 1985 was "not accurate or scientifically supported" and the expert who testified was "entirely wrong."[98]

The 2009 National Academy of Sciences study of forensic evidence stated, "In general, the opinions of bloodstain pattern analysis are more subjective than scientific . . . . Extra care must be given to the way in which the analyses are presented in court. The uncertainties associated with bloodstain pattern analysis are enormous."[99] The report concluded that those interpreting blood patterns in court proceedings should have, at minimum, an understanding of applied mathematics, the physics of fluid transfer and the pathology of wounds[100]

The 2016 PCAST report on *Forensic Science in Criminal Courts* addressed "cognitive bias" as a problem. "Cognitive bias" is the way in which human judgments are shaped by factors other than those relevant to the decision at hand. It includes "'confirmation bias," where individuals interpret information, or look for new evidence, in ways that conform to their preexisting belief or assumption.[101] The report cited a study that showed fingerprint examiners can be influenced in their interpretations if they know what other forensic examiners already concluded. The study's authors recommended that those working in forensic labs have minimal exposure to other crime-scene evidence and things like confessions or eyewitness identifications. [102]

Description/Explanation of the Science

> Bloodstain patterns found at scenes can be complex, because although overlapping patterns may appear simple, in many cases their interpretations are difficult or impossible.[103] Workshops teach the fundamentals of basic pattern formation and are not a substitute for experience and experimentation when applying knowledge to crime reconstruction.[104] Such workshops are more aptly applicable for the investigator who needs to recognize the importance of these patterns so that he or she may enlist the services of a qualified expert.[105]

The Minnesota Bureau of Criminal Apprehension, in its description of forensic analysis disciplines, explains the usefulness of bloodstain pattern analysis in this way:

> The recognition and analysis of bloodstain patterns can yield useful investigative information. The general role of the Bloodstain Pattern Analyst in a criminal investigation is to assist in the reconstruction of those events of an alleged incident that could have created the stains and stain patterns present at a crime scene, on items of physical evidence recovered from that scene and on items of clothing that were present at the crime scene . . . . The sizes of the individual stains composing a pattern, the shapes of these stains and their distribution relative to one another can be utilized for the purposes of determining how a particular stain or pattern may have been produced. Bloodstain pattern analysis evaluations are conducted to determine what action(s) or sequence of actions could have created the bloodstains and/or patterns observed. Information that may be gained with bloodstain pattern analysis include, for example, the position of the individual when the blood was deposited (sitting, standing, etc.), the relative position of individuals at the time of bloodshed, the possible type of weapon used as well as possible mechanisms that could have produced the blood staining on a surface.[106]

Scientific studies support some aspects of bloodstain pattern analysis. One can tell, for example, if the blood spattered quickly or slowly, but some experts extrapolate far beyond what can be supported. Although the trajectories of bullets are linear, the damage that they cause in soft tissue and the complex patterns that fluids make when exiting wounds are highly variable. For such situations, many experiments must be conducted to determine what characteristics of a bloodstain pattern are caused by particular actions during a crime and to inform the interpretation of those causal links and their variabilities. For these same reasons, extra care must be given to the way in which the analyses are presented in court. The uncertainties associated with bloodstain pattern analysis are enormous.[107]

3.10.8 Shaken Baby Syndrome (SBS)

Admissibility

Courts have admitted expert testimony regarding the theory SBS as well as testimony criticizing its premise.[108] Federal Rule of Evidence 702 Advisory Committee Notes acknowledges that it may be proper to admit opposing scientific theories under *Daubert*.[109]

Many courts admit both expert testimony about Shaken Baby Syndrome and testimony criticizing the theory. That is permissible under FRE 702.

Description/Explanation of the Science

The Mayo Clinic defines shaken baby syndrome—also known as abusive head trauma, shaken impact syndrome, inflicted head injury or whiplash shake syndrome—as "a serious brain injury resulting from forcefully shaking an infant or toddler."[110]

Shaken baby syndrome destroys a child's brain cells and prevents his or her brain from getting enough oxygen. Shaken baby syndrome is a form of child abuse that can result in permanent brain damage or death.[111]

> '[T]he conclusions that are . . . reached [about shaken baby syndrome] . . . are for the most part anecdotal.' Dr. Travis Hindman, a prosecution witness in *People v. Lind*, 718 N.E.2d 316, 324 (Ill. 1999). 'Shaken baby syndrome [does] not exist. [It is] 'the medical scandal of the last 20 years'." Dr. John Plunkett, defense witness in *In re J.M.*, 2009 WL 1862523, at *10 (Cal. Ct. App. 2009).[112]

As Professor Imwinkelried noted above, said,

> . . . there was formerly a consensus, especially among pediatricians and pathologists, that violently shaking an infant can cause fatal brain injury. In many cases, the autopsy revealed such injuries, a caregiver acknowledged shaking the child, but there was no evidence that the child's head had struck a surface or object.
>
> Later, biomechanical experts conducted experiments with primates and anthropomorphic models of infant necks. The experiments suggested that shaking alone cannot generate enough force to cause fatal brain injury.
>
> Nevertheless, in 2016 the Ninth Circuit Court of Appeals ruled that the biomechanical research had not invalidated the SBS theory to the extent that a defendant convicted on the basis of SBS was entitled to relief. In the court's words, although the new research had prompted 'a vigorous debate' over SBS, the research did not discredit SBS to the same extent that [CBLA] has been exposed.
>
> There are doubts about whether the biomechanical findings can be extrapolated to human infants. And further research is complicated by the fact that medical ethics precludes subjecting infants to violent shaking to test the premise.[113]

In synopsizing Professor Imwinkelried's article, Professor Kevin Cole of the University of San Diego School of Law wrote the following in his CrimProf Blog,

Although many articles have been written about the admissibility of SBS and its critiques, to date no article has addressed the question of the legal sufficiency of SBS testimony. The question is certainly now timely; in a trilogy of decisions dated 2007, 2010, and 2011, the Supreme Court reversed the Ninth Circuit which had thrice ruled the evidence in an SBS case legally insufficient to sustain a conviction. The question not only concerns SBS; it also raises the broader question of the scope of the Supreme Court's landmark 1979 legal sufficiency decision, Jackson v. Virginia. Some courts have read Jackson narrowly as contemplating that the judge conducting the sufficiency analysis will consider only the prosecution testimony. This article argues that Jackson mandates that the judge consider the defense testimony in the record as well as the prosecution evidence. In addition, the article contends that by restricting the judge's inquiry to the contents of learned treatises admissible under Federal Rule of Evidence 803(18), an expanded Jackson analysis can be conducted without usurping the jury's constitutional role under the Sixth Amendment. Finally, the article applies this mode of analysis to the SBS controversy and concludes that given the current state of the empirical record, standing alone SBS testimony is legally insufficient to prove causation.[114]

The criticism of "shaken baby syndrome" highlights the questions raised by the National Research Council of the National Academies, as well as the President's Council of Advisors on Science and Technology regarding the current state of forensic science and testimony from forensic experts. For the judiciary, these concerns must be considered in deciding whether to allow forensic testimony under FRE 702 and *Daubert/Frye* analysis and then, if the testimony is allowed, how much weight to give it and how far to let each expert go in providing their opinions.

3.10.9 A Sampling of Cases

Firearms / Tool Marks

People v. Jones, 34 N.E.3d 1065 (Ill. App. Ct. 2015), *vacated sub nom*. 2015 WL 13123108 (Ill. 2015). The "expert's testimony lacked an adequate foundation where the expert testified that he found 'sufficient agreement' but did not testify to any facts that formed the bases or reasons for this ultimate opinion that the bullet matched defendant's gun."

Clemons v. State, 896 A.2d 1059 (Md. 2006). "The conclusory aspects of CBLA [comparative bullet lead analysis] are not generally accepted within the scientific community and thus are not admissible under the *Frye-Reed* standard for admitting scientific expert testimony."

State v. Raynor, 189 A.3d 652 (Conn. App. Ct. 2018).

In re Pers. Restraint of Trapp, 165 Wash. App. 1003 (2011).

Fowler v. State, 194 A.3d 16 (Del. 2018).

Parker v. State, 2018 WL 1602585, (Miss. Ct. App. Apr. 3, 2018), *reh'g denied* (Sept. 4, 2018), *cert. granted*, 258 So. 3d 284 (Miss. 2018).

State v. Allen, 2017-0306 (La. Ct. App. 2017), *writ denied*, 2017-2180 (La. 2018), 253 So. 3d 798.

Commonwealth v. Morales, 2017 WL 1957754 (Pa. Super. Ct. 2017).

Severance v. Commonwealth, 799 S.E.2d 329 (Va. Ct. App. 2017), *aff'd*, 816 S.E.2d 277 (Va. 2018).

Com. v. Urritia, 2015 WL 7721897 (Pa. Super. Ct. 2015).

State v. Sisneros, 314 P.3d 665 (N.M. 2013).

People v. Blacknell, 2015 WL 6157479 (Cal. Ct. App. 2015).

People v. Picasso, 2017 WL 4857013 (Cal. Ct. App. 2017), *reh'g denied* (Nov. 9, 2017), *review denied* (CA. 2018).

People v. Hoskins, 2017 WL 3090592 (Mich. Ct. App. 2017).

State v. Cox, 779 N.W.2d 844 (Minn. 2010).

Moody v. State, 2017 WL 829820, (Tenn. Crim. App. 2017), *appeal denied* (June 9, 2017).

State v. Shine, 113 N.E.3d 160 (Ohio Ct. App. 2018).

Lewis v. State, 2014 WL 7204708 (Tex. Crim. App. 2014).

Questioned Documents (Including Handwriting, Ink, Ink Marks)

State v. Clifford, 121 P.3d 489 (Mont. 2005). Rule of evidence did not require trial court to hold *Daubert* hearing before admitting testimony of handwriting expert.

Riley v. State, 102 N.E.3d 353 (Ind. Ct. App. 2018), *transfer denied*, 110 N.E.3d 1147 (Ind. 2018).

State v. Livanos, 725 P.2d 505 (Ariz. Ct. App. 1986). "Practical training and experience" alone are not enough to clearly qualify as an expert regarding questioned documents.

Carroll v. State, 634 S.W.2d 99 (Ark. 1982). "Practical training and experience" alone are not enough to clearly qualify as an expert regarding questioned documents.

Tomlin v. Commonwealth, 2017 WL 972169 (Va. Ct. App. 2017).

State v. Green, 2017 WL 2535899 (N.J. Super. Ct. App. Div. 2017).

Pettus v. United States, 37 A.3d 213 (D.C. 2012).

Hooten v. State, 492 So. 2d 948 (Miss. 1986).

Cooper v. State, 174 P.3d 726 (Wyo. 2008).

Commonwealth v. Ramsey, 2016 WL 5790757 (Pa. Super. Ct. 2016).

Mitchell v. Madison Cty. Sheriff's Dep't, 325 S.W.3d 603 (Tenn. Ct. App. 2010).

Forreston State Bank v. Diehl, 2015 IL App (2d) 150384-U (Ill. Ct. App. 2015).

Virgin Islands v. Todmann, 2010 WL 684009 (V.I. 2010).

Trace Evidence

State v. Gissendanner, 2015 WL 6443194 (Ala. Crim. App. 2015), *rev'd in part sub nom*. Ex parte Gissendanner, 2019 WL 101611 (Ala. 2019).

State v. McGuire, 16 A.3d 411 (N.J. App. Div. 2011).

People v. Escort, 91 N.E.3d 483 (Ill. Ct. App. 2017).

Boyd v. State, 200 So.3d 685 (Fla., 2015).

State v. Blevins, 2018 WL 4265513 (Ohio Ct. App. 2018) *appeal not allowed*, 114 N.E.3d 215 (Ohio 2018).

Molina v. State, 2011 WL 5398174 (Tex. Crim. App. 2011).

State v. Jones, 749 S.W.2d 356 (Mo. 1988).

Biological/Serology Screening (Hair, Fingernails, Blood Type, Etc.)

People v. Reilly, 196 Cal.App.3d 1127 (Cal. Ct. App. 1987). " . . . electrophoretic testing of dried bloodstain evidence is generally accepted as reliable in the relevant scientific community. "

Funderburk v. Com., 368 S.E.2d 290 (Va. 1988). Testimony of the forensic serologist concerning " . . . statistical prevalence in the general population of persons possessing victim's blood . . . " characteristics was properly admitted.

Graham v. State, 308 S.E.2d 413 (Ga. Ct. App. 1983). Testimony of expert witness on identification of blood samples based on procedure known as electrophoresis, " . . . concerning statistical or mathematical probability of certain enzymes being found in the blood of the general population . . . " was properly admitted.

People v. Seda, 529 N.Y.S.2d 931 (N.Y. Sup. Ct. 1988). "This court concludes that the 4-in-1 system [of electrophoresis] employed here has not gained general acceptance in the scientific community."

State v. Dirk, 364 N.W.2d 117 (S.D. 1985). Trial court did not abuse its discretion in admitting expert testimony and test results concerning enzyme analysis of the blood.

State v. Ferguson, 54 So.3d 152 (La. Ct. App. 2010). Retired criminalist was properly accepted as expert in serology in murder prosecution. "He worked for the NOPD for thirty-two years with twelve of those years served in the crime lab performing serology testing. His education included receiving a Bachelor of Science degree in biological science from Louisiana State University in 1965 and a Master of Arts degree in marine biology from California State University in 1968. He had previously been qualified as an expert in serology in other sections of Criminal District Court."

Hair analysis

Commonwealth v. Chmiel, 173 A.3d 617 (Penn. 2017). Court granted post-conviction relief in part based upon hair analysis testimony which exceeded the limits of science and overstated to the jury the significance of microscopic hair analysis. "The FBI now has publicly repudiated the use of microscopic hair analysis to 'link a criminal defendant to a crime.'"

Johnson v. State, 2016 WL 7176765 (Fla. 2016).

Duckett v. State, 231 So.3d 393 (Fla. 2017).

Partin v. Com., 337 S.W.3d 639 (Ky. Ct. App. 2010). State police forensic examiner testified certain hair was similar to the victim's hair, while further testifying other was dissimilar to the victim's hair.

Richardson v. Superior Court, 183 P.3d 1199 (Cal. 2008). The prosecution's second expert, Morton, acknowledged the limits of hair analysis on "cross-examination when he testified that the most that could be said about a hair sample was that it was 'consistent' with an individual's hair and 'could be from that individual.'"

Imperial Cty. Dep't of Soc. Servs. v. J.M. (In re J.M.) 2018 WL 1442488 (Cal. Ct. App. 2018). "In this case of apparent

first impression in California, we hold that the Imperial County Department of Social Services (Department) failed to meet its burden under *People v. Kelly* [citation] of showing that testing hair for marijuana and methamphetamine has gained general acceptance in the scientific community."

U.S. Brown, 557 F.2d 541 (1977). "After extensive review of the record, we are inclined to agree with Appellant that the Government failed to fulfill the threshold requirement of demonstrating that ion microprobic analysis is a generally accepted procedure for comparing samples of human hair and that the experiments conducted by their experts carry sufficient indicia of reliability and accuracy to be said to cross "the line between the experimental and demonstrable stages."

Footwear

Rodriguez v. State, 30 A.3d 764 (Del. 2011). Trial court did not abuse its discretion in prosecution for arson and other offenses in finding that latent fingerprint examiner qualified as an expert in tire track and shoe print analyses. "Here, the record shows that Hegman participated in an FBI course of instruction that covered tire track and shoeprint analysis, independently studied a leading treatise on the discipline, and previously testified on the analysis of tire tracks and shoeprints in Delaware courts. Hegman also demonstrated knowledge of the variables that could affect impressions, including the type of surface and degree of tire inflation."

State v. Brewczynski, 294 P.3d 825 (Wash. Ct. App. 2013). Trial court did not abuse its discretion in admitting witness's expert testimony about footwear impression evidence in murder case; witness qualified as an expert due to his training and experience, his testimony was helpful to the jury, footwear analysis was generally accepted in the forensic community, and witness's methodology was a question of weight for the jury, rather than an issue of admissibility.

State v. Patel, 2016 WL 8135385 (Conn. Super. Ct. 2016). "Ms. Ragaza testified that, in her opinion, footwear comparison analysis is generally accepted in the relevant scientific community."

State v. Jones, 681 S.E.2d 580 (S.C. 2009). "Based on our decision in *Jones I* and the lack of any subsequent research developments which would validate 'barefoot insole impression' evidence, we find the trial judge erred in denying Jones's motion to suppress this evidence.. . . we find the evolution of this evidence post-*Jones I* has not deemed it scientifically reliable."

State v. Gay, 145 A.3d 1066 (N.H. 2016). "We conclude, therefore, that expert testimony on this issue [Footwear Impressions] satisfied the purpose of Rule 702 by providing evidence that could 'assist the trier of fact to understand the evidence or to determine a fact in issue.' N.H. R. Ev. 702."

State v. Thurber, 420 P.3d 389 (Kan. 2018). A "forensic scientist, testified he took photographs and casts of 'footwear impressions' at the Kaw Wildlife Area" and testified "the impressions along the path were consistent with footwear worn" by the defendant and victim.

Fingerprints

U.S. v. Crisp, 324 F.3d 261 (4th Cir. 2003). "While Crisp may be correct that further research, more searching scholarly review, and the development of even more consistent professional standards is desirable, he has offered us no reason to reject outright a form of evidence that has so ably withstood the test of time . . . . Ultimately, we conclude that while further research into fingerprint analysis would be welcome, 'to postpone present in-court utilization of this bedrock forensic identifier pending such research would be to make the best the enemy of the good.'"

Rodriguez v. State, 30 A.3d 764 (Del. 2011). Trial court did not abuse its discretion in prosecution for arson and other offenses in finding that latent fingerprint examiner qualified as an expert in tire track and shoe print analyses. "Here, the record shows that Hegman participated in an FBI course of instruction that covered tire track and shoeprint analysis, independently studied a leading treatise on the discipline, and previously testified on the analysis of tire tracks and shoeprints in Delaware courts. Hegman also demonstrated knowledge of the variables that could affect impressions, including the type of surface and degree of tire inflation."

Anderson v. State, 220 So.3d 1133 (Fla. 2017). There is no requirement that a witness be "certified" in a particular field in order to be deemed an expert and allowed to give opinion testimony. [The witness'] specialized knowledge, training, and extensive experience were sufficient for the trial court to qualify him as an expert on Tire Impression evidence.

In re Norman, 2015 WL 5943643 (N.J. Super. Ct. App. Div. 2015). "Crime scene investigators went to the lot identified by A.F. where they observed tire impressions, boot impressions, and they found a broom stick or pole. Forensic analysis proved that the tire impressions were consistent with tires on the police car driven by Ingram . . . . The Commission accepted the forensic evidence, including the tire impressions, boot impressions, and pole with fibers matching fibers from A.F.'s sweatshirt, as corroborating A.F.'s testimony. A fact finder is not to give greater or lesser weight to the testimony of a police officer merely because of his or her status as a police officer and the Commission was critical of the ALJ's attributing credibility to appellant based, in part, on his status as a police officer."

Bitemarks

Coronado v. State, 384 S.W.3d 919 (Tex. Ct. Crim. App. 2012). Court cannot conclude the trial court abused its discretion in admitting the testimony of expert in forensic dentistry concerning bite mark analysis was admissible in prosecution for injury to a child.

Howard v. State, 701 So. 2d 274 (Miss. 1997). "This Court has never ruled directly on the admissibility or reliability of bite-mark identification evidence, though it has addressed cases in which bite-mark evidence was an issue. . . . While few courts have refused to allow some form of bite-mark comparison evidence, numerous scholarly authorities have criticized the reliability of this method of identifying a suspect. . . . There is little consensus in the scientific community on the number of points which must match before any positive identification can be announced. . . . Because the opinions concerning the methods of comparison employed in a particular case may differ, it is certainly open to defense counsel to attack the qualifications of the expert, the methods and data used to compare the bite marks to persons other than the defendant, and the factual and logical bases of the expert's opinions. Also, where such expert testimony is allowed by the trial court, it should be open to the defendant to present evidence challenging the reliability of the field of bite-mark comparisons. . . . Only then will the jury be able to give the proper weight, if any, to this evidence."

Meadows v. Com., 178 S.W.3d 527 (Ky. Ct. App. 2005). "Dr. Smock gave his expert opinion that the physical findings were consistent with Meadows's account of suffering a bite to the penis. . . . Dr. Smock did not attempt to identify who made the bite based on the bite mark. He conceded that he could not determine whether the bite was intentional or accidental based upon the appearance of the bite mark. Regarding the force used, he could only say that a considerable amount of force would be required to break the skin and damage the blood vessels in the urethra."

Blood Pattern Evidence (aka Blood Spatter)

Jones v. State, 918 So.2d 1220 (Miss. 2005). Trial court did not abuse its discretion by admitting expert's opinion testimony concerning blood pattern on murder defendant's shirt.

Commonwealth v. Merry, 453 Mass. 653, 667 n. 13 (2009). An expert on blood splatter was not necessary for prosecutor to argue how defendant's blood got on air bag because jury could draw own conclusions about source of blood.

People v. Ramos, 388 P.3d 888 (Colo. 2017). "[A]n ordinary person would not be able to testify reliably about the difference between blood cast-off and blood transfer. Therefore, we affirm the court of appeals' holding that the trial court abused its discretion by not qualifying a police detective's blood testimony as expert testimony."

Hudson v. State, 146 S.W.3d 380 (Ark. Ct. App. 2004). Police officer's "testimony established that he had received extensive training and education in blood-spatter analysis, as well as experience in conducting this analysis at crime scenes. It was also established that blood-spatter analysis was a well-recognized science, which has been in existence for many years . . . . In fact, [the officer] testified that he had previously been certified by a trial court in this state as an expert and had testified regarding blood-pattern analysis."

Simpson v. Com., 2013 WL 5988567 (Va. Ct. App. 2013). "The testimony concerning the blood spatter evidence involved a matter beyond the scope or knowledge of the average juror and was a topic within the peculiar knowledge, science, and skill of the expert witness. Indeed, the Supreme Court has stated that blood spatter analysis "involves the application of principles of physics, chemistry, biology, and mathematics."

Johnson v. State, 2018 WL 3359559 (Md. Ct. Spec. App. 2018) "O'Dell used the generally accepted scientific technique of bloodstain pattern analysis to examine bloodstain patterns on Johnson's clothes and determine from that analysis whether the blood on Johnson's clothes could have resulted from his supposed interactions with a man away from the crime scene. The fact that another expert witness disagreed about the results of O'Dell's analysis did not create a *Frye-Reed* issue."

People v. Lyons, 2017 IL App (1st) 141334-U (2017), *appeal denied*, 93 N.E.3d 1070 (Ill. 2017). The testimony of the State's blood spatter expert was not required to be excluded when a proper foundation was laid for his testimony.

Shaken Baby Syndrome (SBS)

People v. Snell, 2011 WL 10088352 (Ill. Ct. App. 2011). "We acknowledge defendant's argument that no Illinois reviewing court has ever determined that shaken baby syndrome satisfies *Frye* . . . . Indeed, defendant does not cite, and our research has not revealed, any Illinois decisions that hold that shaken-baby syndrome evidence is not generally accepted . . . . We also note that for some time, courts in other states have found shaken baby syndrome to be a generally accepted diagnosis in the medical community"

McDonald v. State, 101 So. 3d 914, 915 (Fla. Dist. Ct. App. 2012). Trial court's error in denying indigent defendant's motion for appointment of expensive out-of-state expert witness without exploring less expensive options was not harmless in prosecution for simple child abuse involving shaken baby syndrome. "Interestingly, this is one area in the law where the science is used to prove all elements of the crime. In many cases it comes down to science and nothing more than that. . . . And, it appears that in the relevant

scientific community there are some experts who question the hypotheses underlying opinions similar to those presented by the State from its four experts in this case."

Com. v. Millien, 50 N.E.3d 808 (Mass. 2016). Defense counsel was ineffective for not requesting funds for expert witness. "Therefore, had Dr. Uscinski's expert testiony been offered at trial, the defendant could have challenged Dr. Newton's opinion as to the cause of Jahanna's head injuries."

State v. Saavedra Ruiz, 197 Wash. App. 1015 (2016). "Although the expert medical testimony presented in Saavedra Ruiz's trial linked symptoms of Natalie's brain injuries with shaken baby syndrome, it is clear from the record that the State did not allege that a shaking event caused her death. Unlike the victim in *Fero*, Natalie suffered a skull fracture. Here, Dr. Clark testified that Natalie's death was caused by blunt force trauma to the back of her head."

3.10.10 Endnotes

1 Nat'l Research Council, Strengthening Forensic Science in the United States: A Path Forward 4 (2009), http://www.nap.edu/catalog/12589.html

2 *Id*.

3 *Id*.

4 Laura Tierney, *Analysis, Comparison, Evaluation, and Verification* (ACE-V), *in* Encyclopedia of Forensic Sciences (2013)

5 R.A. Huber, A.M. Headrick, Handwriting Identification and Facts and Fundamentals, (CRC Press, 1999).

6 R.A. Huber, *Expert witnesses*, Crim. Law Q. 2 (1959) 276–295; R.A. Huber, *The philosophy of identification*, RCMP Gazette (1972) 9–14.

7 David R. Ashbaugh, Quantitative-Qualitative Friction Ridge Analysis, (1999)

8 Report to the President: Forensic Science in criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods at 3. (September 2016). https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_forensic_science_report_final.pdf

9 Nat'l Research Council, *supra* note 1.

10 John Butler, *U.S. initiatives to strengthen forensic science & international standards in forensic DNA*, 18 Forensic Sci. Int. Genet. 4 (2015).

11 U.S. Dep't. J., Office of the Att'y Gen., Memorandum for Heads of Department Components, Recommendations of the National Commission on Forensic Science, (September 6, 2016), https://www.justice.gov/opa/file/891366/download

12 Daubert v. Merrell Dow Pharmaceuticals, Inc., 509 U.S. 579 (1993).

13 Nat'l Research Council, *supra* at 1.

14 Report to the President, *supra* at 8.

15 *Id*.

16 Lauren J. Young, *The Flaws In Forensic Science*, Science Friday, May 30, 2017, https://www.sciencefriday.com/articles/the-flaws-in-forensic-science/.

17 Report to the President, *supra* at 8.

18 Examiners can also undertake other kinds of analysis, such as for distance determinations, operability of firearms, and serial number restorations as well as the analyze primer residue to determine whether someone recently handled a weapon. Also, for more complete descriptions, *see, e.g.*, Nat'l Research Council, *supra* note 1; Is a Match Really a Match? A Primer on the Procedures and Validity of Firearm and Toolmark Identification, Fed. Bureau Investigation, archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/july2009/review/2009_07_review01.htm (last visited April 14, 2019).

19 *Id*.

20 Nat'l Research Council, Ballistic Imaging 3-4 (Nat'l Acad. Press. 2008).

21 Report to the President, *supra* note 8 at 105.

22 J. Song, et. al., *Estimating error rates for firearm evidence identifications in forensic science*, Forensic Sci. Int'l., 13 December 2017.

23 Fed. R. Evid. 702; Jeremy Dack, *Using Forensic Ballistics in The Courtroom* 637 Seton Hall L. School Student Scholarship at 5 (2014). https://scholarship.shu.edu/student_scholarship/637

24 Nat'l Research Council, *supra* note 1, at 150-152.

25 Nancy Ritter, *The Science Behind Firearm and Tool Mark Examination*, 274 Nat'l Inst. Just. J. 20 (2014), https://www.nij.gov/journals/274/Pages/firearm-toolmark-examination.aspx

26 *Id*.

27 *Id*.

28 *Id*.

29 Dack, *supra* note 23 at 6

30 *Id*., at 7-8.

31 Report to the President, *supra* note 8 at 111.

32 Edward lmwinkelried & William Tobin, *Comparative Bullet Lead Analysis (CBLA) Evidence: Valid Inference or Ipse Dixit?*, 28 Okla. City U. L. Rev. 43 (2003); Erik Randich et al., *A Metallurgical Review of the Interpretation of Bullet Lead Compositional Analysis*, 127 Forensic Sci. Int'l 174 (2002) (Tobin was a coauthor); William Tobin & Wayne Duerfeldt, *How Probative is Comparative Bullet Lead Analysis?*, 17 Crim. Just. 26 (Fall 2002); Paul Giannelli, *Comparative Bullet Lead Analysis: A Retrospective*, Case West. Reserve U. School L. Faculty Pub. (2010), https//scholarlycommons.law.case.edu/faculty_publications/97.

33 *Id*.

34 *Id*.

35 *Id*.

36 *Id*.

37 Edward Imwinkelried, *When New Research Proves Courtroom 'Experts' Wrong*, Crime Rep. (July 28, 2017). https://thecrimereport.org/2017/07/28/when-new-research-proves-courtroom-experts-wrong/

38 Michael Risinger, *Cases Involving the Reliability of Handwriting Identification Expertise Since the Decision in Daubert*, 42 Tulsa L. Rev. (Winter 2007), http://digitalcommons.law.utulsa.edu/tlr/vol43/iss2/11

39 Nat'l Research Council, *supra* note 1, at 163-167, citing *Standard Descriptions of Scope of Work Relating to Forensic Document Examiners* (American Society for Testing and Materials [ASTM] Designation E 444 -98) (1998), *Standard Guide for Test Methods for Forensic Writing Ink Comparison* (ASTM Designation E 1422 -01) (2001), *Standard Guide for Writing Ink Identification* (ASTM Designation E 1789 -04) (2004), and *Standard Guide for Examination of Handwritten Items* (ASTM Designation E 229 0-03) (2003).

40 *Id*.

41 M. Kam, et al., *Writer identification by professional document examiners* 42 J. Forensic Sci. 778 (1997), reports on proficiency tests given to more than 100 questioned document examiners and to a control group of individuals with similar educational backgrounds. Each subject made 144 pair-wise comparisons. Although

the study showed that document examiners are much more accurate than lay people in determining whether or not two samples "match" (based on the "identification" and "strong probability" definitions of ASTM standard E1658), professionals nonetheless declared an erroneous match in 6.5 percent of the comparisons. A similar, more recent study, focusing on whether individual signatures were genuine, is reported in J. Sita, et al., *Forensic handwriting examiners' expertise for signature comparison*. 47 J. Forensic Sci. 1117 (2002). That study found that professional handwriting examiners erred in 3.4 percent of their judgments.

42 Nat'l Research Council, *supra* note 1, at 167.

43 M. Merlino Nat'l Inst. Just., U.S. Dept. Just., Validity, reliability, accuracy and bias in forensic signature identification (2015).

44 C. Roux, et al., *The end of the (forensic science) world as we know it? The example of trace evidence,* 370 Phil. Trans. R. Soc. (2015). http://dx.doi.org/10.1098/rstb.2014.0260.

45 J. Robertson & C. Roux, *Trace evidence: here today, gone tomorrow?* 50 Sci. Just. 18 (2009).

46 D. Hazard & P. Margot, *Forensic Science Culture* in Encyclopedia of Criminology & Crim. Just., at 1782–1795 (G. Bruinsma G. & D. Weisburd eds., Springer 2014).

47 C. Roux, et. al., *From forensics to forensic science,* 24 Curr. Issues Crim. J. 7 (2012); Nat'l Research Council, *supra* note 1.

48 C. Roux, *supra* note 65.

49 Forensic Resources, North Carolina Office of Indigent Defense Services, http://www.ncids.com/forensic/serology/serology.shtml (last visited April 14, 2019).

50 Nat'l Research Council, *supra* note 1, at 128-133.

51 *Id*.

52 *Id*.

53 Imwinkelried, *supra* note 37.

54 Nat'l Research Council, *supra* note 1 at 47.

55 M.M. Houck & R.E. Bisbing, *Forensic human hair examination and comparison in the 21st century* 17 Forensic Sci. Rev. 7 (2005).

56 *Id*.

57 *Id*.

58 *See also* DJ McAneny, *Delaware DOJ announces review of convictions on the back of faulty hair evidence analysis method before 2000*, WDEL, (March 4, 2019), (Delaware Department of Justice announcement of independent review of criminal convictions obtained prior to the year 2000 on the back of a "highly unreliable" hair comparison analysis method resulting in "potentialy questionable hair evidence" used in those cases). https://www.wdel.com/news/delaware-doj-announces-review-of-convictions-on-the-back-of/article_f8eb80b0-3eb6-11e9-8adf-f790de5bca08.html?fbclid=IwAR2hWZCtHhgUIJW1orCGc90FtU9S_pZxb4R-8SJ1u_0n6VOcjayW6I6ovtI

59 Nat'l Research Council, *supra* note 1 at 155-161.

60 *Id*.

61 See Dept. J. Proposed Uniform Language for Testimony and Reports for the Forensic Hair Examination Discipline, www.justice.gov/dag/file/877736/download *and* Supporting Documentation for Dept. J. Proposed Uniform Language for Testimony & Reports for the Forensic Hair Examination Discipline, www.justice.gov/dag/file/877741/download.

62 Report to the President, *supra* note 8 at 121.

63 *Id*.

64 Report to the President, *supra* note 8 at 121-122.

65 *Id*.

66 *See* SWGTREAD Range of Conclusions Standards for Footwear and Tire Impression Examinations (2013). SWGTREAD Guide for the Examination of Footwear and Tire Impression Evidence (2006) and Bodziak, Footwear Impression Evidence: Detection, Recovery, and Examination 347 (2nd ed. 2000).

67 Report to the President, *supra* note 8 at 114-117

68 *Id*.

69 Report to the President, *supra* note 8 at 116.

70 Report to the President, *supra* note 8 at 117.

71 *Id*.

72 *Id*.

73 *Id*.

74 Alex Nabaum, et al., *Bad science puts innocent people in jail — and keeps them there*, Wash. Post, March 21, 2016. https://www.washingtonpost.com/outlook/bad-science-puts-innocent-people-in-jail--and-keeps-them-there/2018/03/20/f1fffd08-263e-11e8-b79d-f3d931db7f68_story.html?utm_term=.e3603e4286a7

75 People v. Marx, 54 Cal. App. 3d 101 (1975).

76 *Id*.

77 *Id*.

78 Nabaum, *supra* note 74.

79 J.A. Kieser., *Weighing bitemark evidence: A postmodern perspective* 1 J. Forensic Sci., Med., & Pathology 75 (2005).

80 Nat'l Research Council, *supra* note 1 at 173-176.

81 American Board of Forensic Odontology

82 I.A. Pretty, *A Web-based survey of odontologists' opinions concerning bite mark Analyses* 48 J. Forensic Sci. 1 (2003).

83 C.M. Bowers, *Problem-based analysis of bite mark misidentifications: The role of DNA*. 159 Forensic Sci. Int'l Supplement 104 (2006).

84 I.A. Pretty & D. Sweet., *The scientific basis for human bitemark analyses—A critical review,* 41 Sci. & Just. 85 (2005) (Quotation taken from the abstract).

85 Nat'l Research Council, *supra* note 1 at 173-176.

86 See ABFO Bitemark Methodology Guidelines, http://abfo.org/ wp-content/uploads/2012/08/ABFO-Standards-Guidelinesfor-Evaluating-Bitemarks-Feb-2018.pdf.

87 *Id*.

88 Gerald LaPorte, *Wrongful Convictions and DNA Exonerations: Understanding the Role of Forensic Science*, 279 J. Nat'l Inst. Just. 10 (2018).

89 Nat'l Research Council, *supra* note 1 at 151.

90 John R. Vanderkolk, *Examination Process, in* The Fingerprint Sourcebook 9-17 (Nat. Inst. of Justice ed., 2011).

91 *Id*.

92 *Id*.

93 *Id*.

94 J.L. Mnookin, *The validity of latent fingerprint identification: Confessions of a fingerprinting moderate* 7 Law, Probability & Risk 127 (2008).

95 M. Saks and J. Koehler, *The coming paradigm shift in forensic identification science*. 309 Sci 892, (Aug. 5, 2005).

96 J.L. Mnookin, *The validity of latent fingerprint identification: Confessions of a fingerprinting moderate* 7 Law, Probability & Risk 127 (2008).

97 *Id*.

98 Pamela Colloff, *Influential Texas Commission Says Blood-Spatter Testimony in Joe Bryan's Murder Case Was "Not Accurate or Scientifically Supported*", N.Y. Times Mag., July 24, 2018.

99 Nat'l Research Council, *supra* note 1 at 178.

100 Report to the President, *supra* note 8 at 31-32.

101 *Id*. at 31-32.

102 *Id*.

103 H.L. MacDonell, Bloodstain Patterns (Laboratory of Forensic Science, 1997); S. James, Scientific and Legal Applications of Bloodstain Pattern Interpretation (CRC Press, 1998). P. Pizzola, et al., *Blood drop dynamics–II*, 31 J. Forensic Sci. 36 (1986); R.M. Gardner, Practical Crime Scene Processing and Investigation (CRC Press, 2004); H.C. Lee, et al., Henry Lee's Crime Scene Handbook 281-298 (Elsevier Acad. Press, 2005).

104 W.J. Chisum & B.E. Turvey, Crime Reconstruction (Elsevier Acad. Press, 2007).

105 Nat'l Research Council, *supra* note 1 at 177-178.

106 Minn. Bureau Crim. Apprehension, Bloodstain Pattern Analysis. https://dps.mn.gov/divisions/bca/bca-divisions/forensic-science/Pages/forensic-programs-crime-scene-bpa.aspx (last visited April 14, 2019).

107 *Id*., at 178-179.

108 Edward J. Imwinkelried, *Shaken Baby Syndrome: A Genuine Battle of the Scientific (and Non-Scientific) Experts*, 46 Crim. L. Bull. 6 (2010).

109 Fed. R. Evid. 702 Advisory Committee Note to 2000 amendment. "When a trial court, applying this amendment, rules that an expert's testimony is reliable, this does not necessarily mean that contradictory expert testimony is unreliable. The amendment is broad enough to permit testimony that is the product of competing principles or methods in the same field of expertise."

110 Mayo Clinic, Shaken Baby Syndrome, https://www.mayoclinic.org/diseases-conditions/shaken-baby-syndrome/symptoms-causes/syc-20366619 (last visited April 14, 2019).

111 *Id*.

112 Imwinkelried, *supra* note 108.

113 Imwinkelried, *supra* note 37.

114 Inwinkelried on Shaken Baby Syndrome, Battles of Experts, and Sufficiency of Evidence, CrimProf Blog, February 1, 2018, https://lawprofessors.typepad.com/crimprof_blog/2018/02/inwinkelried-on-shaken-baby-syndrome-battles-of-experts-and-sufficiency-of-evidence.html