3. Scientific Evidence

Sections 3.1 - 3.9

Hon. Bridget Mary McCormack

3.1 Introduction

The goal of a trial, of course, is to find the truth about disputed questions. It is not unlike science which aims to find the truth about questions regarding the physical and natural world. When the answer to a legal question depends on science, then one might expect the law to provide a warm welcome to the scientific evidence that helps answer the legal question. But it turns out to be more complicated than that.

There is an inherent tension between law and science based on uncertainty.

Scientific evidence features in many legal disputes. The criminal law often engages various forensic disciplines and recently algorithms that promise scientific predictions about "dangerousness." Judges are being asked to make crucial decisions such as granting bail and, if so, with what conditions using these algorithms. Criticisms of them raise equal protection and other important issues. Tort cases and medical malpractice cases often turn on questions relating to scientific evidence about substances or procedures. And courts review administrative agency determinations which often involve adjudicating scientific evidence. But judges are not usually scientists, nor even fluent in the scientific method much less the specific scientific disciplines that might be critical in litigation. And to complicate it further, the disciplines have conflicting methodology, vocabulary, and norms. Law puts a high price on certainty and finality. Science, on the other hand, is comfortable with uncertainty and with open questions. This tension permeates the law/science relationship.

As a result, a judge's job as the gatekeeper of scientific evidence can be a hard one.

3.2 Opinion Evidence: The General Rule

The general rule governing opinion evidence in court is familiar to judges: a witness should testify only about the facts she observed and should not give her opinion about those facts. The rule has a truth-seeking foundation; opinion evidence does not assist a jury or judge and might mislead it. A witness's subjective opinion about an issue in a case is irrelevant. It is for the jury or judge to draw subjective conclusions from the facts, and a witness's opinion interferes with that function. The judge, as gate-keeper, is trained to exclude opinion evidence from lay witnesses, so that the fact-finder can draw its own conclusions about the evidence.

3.3 Scientific Evidence as Opinion Evidence

This particular gatekeeping function is more nuanced with scientific evidence. The exception to the general rule barring opinion testimony is for expert opinions. And expert opinion is commonly how scientific evidence is introduced in litigation.

Expert scientific opinion evidence generally is admissible when a witness's education, training, skill, or experience gives expertise and specialized knowledge in a particular subject beyond that of the average person. The expert's opinion is admissible to assist the fact-finder. Expert witnesses also may testify about facts within their field of expertise. An expert's opinion must be based on admissible evidence. The expert is expected to give the factfinder the evidentiary basis for her opinion so that the factfinder can form an independent judgment about the expert's opinion.

There are jurisdiction-specific rules which govern what scientific opinion evidence can make its way into a proceeding and how so. In the federal system and in many states, understanding the legal architecture around the admission of scientific opinion evidence requires understanding *Daubert v. Merrell Dow Pharmaceuticals, Inc.* 509 U.S. 579 (1993) and Federal Rule of Evidence (FRE) 702.

Before FRE 702 was enacted, courts determined the admissibility of testimony about novel scientific evidence by whether it has "gained general acceptance in the particular field in which it belongs."[1] The trial court was the gatekeeper and was expected to defer to experts in the field in making the determination. In 1993 the Supreme Court held in *Daubert* that the *Frye* test was superseded by the 1975 Federal Rules of Evidence, and specifically by Rule 702 yet seven states still use the *Frye* standard. The *Daubert* Court held that the rules governing expert evidence simply did not support the idea "that 'general acceptance' is an absolute prerequisite to admissibility" of scientific evidence. Moreover, such "a rigid 'general acceptance' requirement would be at odds with the Rules' liberal thrust and their 'general approach of relaxing the traditional barriers to 'opinion' testimony.'"[2]

FRE 702 permits a qualified expert to testify about her opinion if:

a. the expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;

b. the testimony is based on sufficient facts or data;

c. the testimony is the product of reliable principles and methods; and

d. the expert has reliably applied the principles and methods to the facts of the case.

Every jurisdiction has a rule of evidence governing expert opinion evidence, and in most states it is codified as Rule 702. But whether a state uses the *Daubert* or *Frye* standard, some other standard, or a combination of both standards is jurisdiction specific. *Appendix 1* summarizes each state's approach.

3.4 What Distinguishes Scientific and Technical Evidence

The expert opinion rule is not limited to scientific evidence. Rather, it governs "scientific, technical, or other specialized knowledge" which requires an understanding of what distinguishes scientific evidence from technical evidence. The difference between scientific and technical evidence became especially relevant after *Daubert*, as the expert opinion evidence at issue in the case was scientific and some questioned whether the *Daubert* standard should apply equally to technical evidence. That particular debate is salient in few jurisdictions today as *Kumho Tire, Ltd. v. Carmichael*, 526 U.S. 137 (1999), which held that *Daubert* applies not only to scientific testimony but also to technical testimony unrelated to a pure science, settled it.

> *The ultimate question is: "Does the expert opinion assist the finder of fact?"*

Exactly which disciplines are more technical than scientific can be a hard determination, and one about which reasonable people can disagree. For example, before *Kumho Tire* was decided, some fire investigators believed that their discipline was not a science but more a matter of technical evidence and was therefore not subject to *Daubert*. In any jurisdiction that has adopted *Daubert* but not adopted *Kumho Tire*, arson investigation might be an example of a technical discipline.[3] In these jurisdictions technical evidence that is not tied to a specific science is not subject to the *Daubert* standard.

3.5 Expert Opinion

Nor are the rules governing expert opinion testimony limited to scientific and technical evidence. FRE 702 permits expert opinions about all "specialized" knowledge and an expert is any person qualified by "knowledge, skill, experience, training or education." Expert opinions can take many forms: scientific experts, forensic experts, accounting experts, vocational experts, and any other area where a witness has specialized training and education. In many criminal cases, police officers are called to testify as experts about specific criminal activity.

The question for the court will always be whether the expert opinion will assist the factfinder. Disputes around this question are common. The judge's job is to determine whether a particular question is one that a lay jury can decide without the help of someone with specialized knowledge. Expert opinions should be excluded when they are unhelpful and thus superfluous and a waste of time.[4]

3.6 Distinguishing Expert Scientific Opinion from Other Expert Opinion

The difference between scientific expert opinion and other expert opinion is important. As already explained, technical evidence might well be subject to *Daubert*, if a jurisdiction has adopted *Kuhmo Tire*. But expert opinion neither scientific nor technical isn't always a great fit for *Daubert* or *Frye*. For example, it is not uncommon for a litigant to offer a police officer as an expert in gang activity. This subject of how gangs behave isn't scientific or technical, but, the argument goes, the officer's opinion is based on her "specialized knowledge" from her experience. And while the *Daubert* decision does not govern this non-scientific, non-technical category of expert testimony, FRE 702 does not exempt it from its requirements. This may mean that it is harder for the proponent of that testimony to satisfy the rule.

3.7 Legal vs. Scientific Standards

As the preceding sections have shown, the intersection of legal and scientific standards can be complicated. The scientific method encompasses norms and practices for conducting experiments to test a concept, observing the results, making inferences from them and then testing those inferences with further experimentation. In other words, the “truth” is always in development. And scientific disciplines have safeguards for ensuring research and conclusions are sound such as peer review, controlled testing, and error rates.

This approach is categorically different than the legal process. Courts have borrowed some of these tools to determine whether scientific evidence should be admissible. However, the trial is the entire universe of evidence from which the factfinder makes a final decision, and that is the end of the question. Therefore for purposes of sorting out that legal truth, often the law follows slowly behind science, as sciences need to be fairly established (even if not universally accepted) before they become properly admissible in court.

This is so because of concerns of due process and fundamental fairness. The common law structure for trials used in the United States, which at its core relies on constitutional rules to control the admission of evidence, exists to prevent inaccurate factual final judgments.

Scientific standards for integrity and reliability are only a starting point to determine admissibility.

The Sixth Amendment right to confront a witness was created to furnish a procedure to exclude evidence against an accused when its reliability cannot be tested at trial.

In other words, the stakes are different and thus the standards are too. Scientific standards for integrity and reliability are only a starting point for courts in determining legal admissibility. It is also suggested that (a) when scientists and lawyers talk about facts or evidence, each means something different, because (b) differences between science and law are hidden by similarities; and (c) institutional or procedural changes must address (a) and (b) if they are to succeed.

3.8 Cyber and Digital Evidence

The use of Electronically Stored Information (ESI) as evidence at trial has become commonplace. For the court to determine its admissibility properly, it must have a general understanding of the technology and the issues that will determine whether its proponent has properly established its authenticity. Most courts in the United States that have addressed the admissibility of ESI and provided analysis on its admission have applied the Federal Rules of Evidence, and specifically FRE 901. This section will too.

The determination of authenticity of ESI will require the court to develop an understanding of the technology underlying the proposed ESI

ESI is digital evidence. There is not one single exhaustive list of categories of ESI. "ESI comes in multiple 'flavors,' including e-mail, website ESI, internet postings, digital photographs, and computer-generated documents and data files."[5] "Examples of internet postings include data posted by the site owner, data posted by others with the consent of the site owner, and data posted by others without consent, such as by 'hackers.' Examples of computer-generated documents and files include electronically stored records or data, computer simulation, and computer animation."[6]

After the determination of whether the proffered ESI evidence is relevant, a court will need to conduct a detailed inquiry into its authenticity. The determination of authenticity of ESI will require the court to develop an understanding of the technology underlying the proposed ESI, which in turn will enable the court to ask the right questions and appropriately weigh the foundation evidence for its introduction.

Because of the underlying technologies involved in creating and storing ESI, it may have characteristics that make it extremely reliable and probative, but it also may have characteristics that create doubt about its authenticity. The court should recognize this when reviewing the admission of ESI into evidence.

Digital evidence is different than traditional evidence. Digital evidence is easily modifiable. But the fact that it is potentially modifiable is not enough to establish its untrustworthiness.[7] Although a court may decide based on the circumstances not to presume ESI has been modified, the fact that it could be modified, because of advances in technology, create authenticity issues about which courts should be aware. For instance, it has become easier to change the text in scanned documents. In addition to human tampering of evidence, data can be improperly or unexpectedly altered because of a computing error that is user caused or the result of a software defect.

Although ESI is subject to modification that can potentially affect its admissibility, there are positive characteristics of ESI. ESI is difficult to destroy, it is easily duplicated and it is potentially more expressive.

When considering the introduction of ESI, it is important to know how the ESI was created, stored, retrieved and preserved. Whether the ESI is recovered as a result of a warrant or through discovery, ESI obtained/seized should be frozen upon being obtained ("seizing and freezing") to ensure its authenticity.

When someone (including a forensic examiner) obtains ESI from a system, the court will also need to determine whether the activities of the person obtaining the ESI from the system or anyone else modified the data. This inquiry will need the competency of the person who obtained the data and a review of the documentation setting forth how the data were seized/obtained, accessed, stored and transferred to the medium presented to the court.[8] Sufficient documentation must be maintained by the person obtaining the ESI from the system for the court to make a proper determination of its admissibility. Merely accessing data may alter it; thus courts must undertake to determine what alterations may have taken place when assessing the authenticity of ESI being offered into evidence. For instance, if the date that a file was last accessed is the relevant question, simply accessing that file for the pending proceedings by someone inexperienced at preserving ESI in its unaltered form may change the date it was last accessed, thereby altering the proffered evidence.

If ESI results from software processing data inputted, it will be important to understand how the data were first entered, i.e., its source and whether it was entered accurately without interpretation or opinion, or whether there was opinion and analysis applied to the data ultimately inputted.[9] Additionally, the court should review the measures taken to verify the accuracy of any software that processes data.[10] This is ultimately a two-step inquiry for the court to undertake: first, the admissibility of the entered data must be analyzed; and second, the admissibility of the processed data must be analyzed.

Electronically Stored Information must be shown to be an accurate representation of the record that was originally created.

The proponent's ability to demonstrate to the court that the data stored on the computer was merely stored and not altered will resolve many authentication issues. Once stored data has been processed to derive new or different data, additional authentication issues will arise. In *In re Vee Vinhnee*, 336 BR 437, 444 (BAP 9th Cir. 2005), one court's admission analysis of ESI was:

> The primary authenticity issue in the context of business records is on what has, or may have, happened to the record in the interval between when it was placed in the files and the time of trial. In other words, the record being proffered must be shown to continue to be an accurate representation of the record that originally was created.[11]

Authenticity of ESI under FRE 901 will require evidence sufficient to show that the evidence in question is what the proponent claims.[12] This means that the proponent must be able to demonstrate that the record that has been retrieved from the file is the same as the record originally placed into the file.[13] This may be satisfied by:

1. a competent witness,[14]
2. a "process or system" used to produce the result and showing that the process or system produces an accurate result,[15] or
3. "the appearance, contents, substance, internal patterns, or other distinctive characteristics of the item taken together with all the circumstances."[16]

This list is not exhaustive.

The *In re Vee Vihnee* Court explained FRE 901(b)(9) in further detail:

> Rule 901(b)(9), which is designated as an example of a satisfactory authentication, describes the appropriate authentication for results of a process or system and contemplates evidence describing the process or system used to achieve a result and demonstration that the result is accurate.[17] The advisory committee note makes plain that Rule 901(b)(9) was designed to encompass computer-generated evidence and also that it did not preclude taking judicial notice in appropriate circumstances.[18]

To determine whether ESI has been altered or manipulated, its proponent should have some form of audit procedures to assure the integrity of the records, which may include records of regular testing the computer and its software for potential errors.[19] A witness supporting the authentication of ESI should be able to "testify as to the mode of record preparation, that the computer is the standard acceptable type, and that the business is conducted in reliance upon the accuracy of the computer in retaining and retrieving information."[20]

Professor Edward J. Imwinkelried set forth an eleven-step inquiry for electronic business records, which serves as an excellent framework to analyze the authenticity of ESI.[21] Professor Imwinkelried perceives electronic records as a form of scientific evidence and employs this eleven-step foundation for computer records:

1. The business uses a computer.
2. The computer is reliable.
3. The business has developed a procedure for inserting data into the computer.
4. The procedure has built-in safeguards to ensure accuracy and identify errors.
5. The business keeps the computer in a good state of repair.

6. The witness had the computer readout certain data.
7. The witness used the proper procedures to obtain the readout.
8. The computer was in working order at the time the witness obtained the readout.
9. The witness recognizes the exhibit as the readout.
10. The witness explains how he or she recognizes the readout.
11. If the readout contains strange symbols or terms, the witness explains the meaning of the symbols or terms for the trier of fact.

Once the proponent of ESI can demonstrate through a *prima facie* showing that the evidence is what it is claimed to be, then the opponent's claimed flaws about its authenticity will go to its weight, not its admissibility.[22]

Throughout a court's assessment of ESI, additional issues may arise. Although not all digital evidence is hearsay, some of it is in which case, the court will need to determine whether one of the hearsay exceptions under FRE 803, 804 or 807 apply. For instance, "[w]here postings from internet websites are not statements made by declarants testifying at trial and are offered to prove the truth of the matter asserted, such postings generally constitute hearsay under Fed. R. Evid. 801."[23]

The next step in determining the admissibility of electronic evidence is to analyze issues associated with Fed. R. Evid. 1001-1008. The *Lorraine* Court provides a detailed analysis of the issues associated with the original writing rule.[24]

The last step in determining the admissibility of electronic evidence is to analyze it to determine whether its probative value outweighs any unfair prejudice.[25]

3.9 Endnotes

1. Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).
2. Daubert v. Merrell Dow Pharmaceuticals, Inc. 509 U.S. 579, 588 (1993).
3. *But see* Michigan Millers Mut. Ins. Corp. v. Benfield, 140 F.3d 915 (11th Cir. 1998).
4. 7 J. WIGMORE, WIGMORE ON EVIDENCE § 1918.
5. Lorraine v. Markel American Ins Co, 241 F.R.D. 534, 538 (D.Md. 2007).
6. *Id*., 241 F.R.D. at 538 n. 4, citing 2 MCCORMICK ON EVIDENCE § 227 (John William Strong, et al. eds., 6th ed. 2006); Gregory P. Joseph, *Internet and Email Evidence*, 13 PRAC. LITIGATOR (Mar 2002), *reprinted* in 5 STEPHEN A. SALTZBURG, ET AL., FEDERAL RULES OF EVIDENCE MANUAL § 4 at 20 (9th ed. 2006); Paul W. Grimm & Claudia Diamond, *Low-Tech Solutions to High-Tech Wizardry: Computer Generated Evidence*, 37 MD. B.J. 4 (July/August 2004).
7. United States v. Bonallo, 858 F.2d 1427, 1436 (9th Cir. 2013).
8. DANIEL J. RYAN & GAL SHPANTZER, LEGAL ASPECTS OF DIGITAL EVIDENCE (2016), at 3-4.
9. United States v Scholle, 553 F.2d 1109, 1125 (8th Cir. 1977).
10. *Id*.
11. In re Vee Vinhnee, 336 B.R. 437, 444 (B.A.P. 9th Cir. 2005).
12. FRE 901(a); *See also* United States v Lubich, 72 M.J. 170 (2013).
13. FRE 901(a).
14. FRE 901(b)(1).
15. FRE 901(b)(9).
16. FRE 901(b)(4).
17. FRE 901(b)(9).
18. *In re Vee Vinhnee*, 336 B.R. at 446.
19. *Id*. at 445.
20. *Id*. at 445-446 (citing BARRY RUSSELL, BANKRUPTCY EVIDENCE MANUAL, at § 803.17 (2005) (“Russell”); *cf*. 5 Weinstein § 900.07[1][c]).

21. *In re Vee Vinhnee*, 336 B.R. at 446, *citing* EDWARD J. IMWINKELRIED, EVIDENTIARY FOUNDATIONS (5th ed. 2002).

22. *Lubich*, at 174 (2013)

23. People v Johnson, 51 Misc.3d 450, 465 (2015).

24. Lorraine v. Markel American Ins Co, 241 F.R.D at 576-583.

25. *Id.*

3. Scientific Evidence

Section 3.10
Forensic Pattern Evidence

Marc Picker, Esq.

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.
>
> 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.

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

> 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]

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]

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

> 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.

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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.'"

Tire impressions, etc.

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

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3. Scientific Evidence

Section 3.11
Forensic Analytical Evidence

Hon. Kevin Burke

3.11.1 Introduction

Forensic science is the application of scientific knowledge to legal problems in trials, civil disputes, and arbitration proceedings. Many forensic science disciplines have physical, chemical, and biochemical principles at their core. This includes drug identification chemistry, forensic toxicology, and several types of trace evidence analyses. There are computer innovations which have greatly increased the capability and accuracy of forensic analytical analysis, but at its core, there is an element of human judgment.

Forensic analysis of most physical and biological evidence is conducted for two purposes: identification and comparison. Identification determines what exactly a particular item or substance is. Is that green leafy substance marijuana or oregano? Is that brown stain dried blood of a human being or an animal? A forensic examiner may offer an opinion that the substance in question is present, not present, or that testing was inconclusive, and the presence of the substance cannot be ruled in or ruled out. Comparisons are made to find out whether a known and a suspect item or substance share a common origin. Did the fingerprint, hair, or blood come from the suspect? Does the paint smudge found on a hit-and-run victim's clothing match that of the suspect's car?

Paul Kirk, in an early treatise on forensic science, *Crime Investigation*, wrote:

> Wherever he steps, whatever he touches, whatever he leaves, even unconsciously, will serve as relevant evidence against him. Not only his fingerprints or his footprints, but his hair, the fibers from his clothes, the glass he breaks, the tool marks he leaves, the paint he scratches, the blood or semen he deposits or collects – all those bear mute witness against him. This is evidence that does not forget. It is not confused by the excitement of the moment. It is not absent because human witnesses are. It is factual evidence. Physical evidence cannot be wrong; it cannot perjure itself; it cannot be wholly absent. Only its misinterpretation can err. Only human failure to find it, study and understand it can diminish its value.[1]

There are few rules of thumb for judges, except one: Every field of forensic science has potential problems. Although infrequent, there are examples of rogue forensic examiners.[2] The American Society of Crime Lab Directors' Laboratory Accreditation Board candidly said, "Forensic scientists are human beings. As such they will sometimes make mistakes and, in some very rare instances, push the boundaries of ethical behavior."[3] Recent court decisions are forcing forensic scientists to improve both the science upon which the technology is based and the competence of expert witnesses in forensic science. Because of the many changes and improvements in the field, the adage "every once in a while, we should hang a question mark after things we take for granted" applies to a judge who must make a decision with forensic analytical evidence.

The qualifications of the forensic scientist are crucial. The more the particular type of forensic analysis is founded on medical research, the more trustworthy the analysis. For example, blood analysis dominates medicine. It is likely every judge has at one point in their life had lab work ordered by their doctor—few have had a personal experience with blood spatter pattern evidence.

Recent court decisions are forcing forensic scientists to improve both the science upon which the technology is based and the competence of expert witnesses in forensic science.

The RAND Forensic Technology Survey[4] study found that there is a pressing need for more and better forensic science technology—and for well-trained people to use it and present its results. Many crime laboratories have substantial backlogs of evidence not yet tested or otherwise processed. Clearing these backlogs is a major concern and goal of laboratory directors. The RAND Forensics Survey found that more than half of the forensic lab workload was for tests of controlled substances, about a sixth was for latent prints, and a ninth was for blood alcohol tests.

There are several highly reputable professional associations of forensic analysts. The American Academy of Forensic Sciences, for example, is a multidisciplinary professional organization that provides leadership to advance science and its application to the legal system. The objectives of the Academy are to promote professionalism, integrity, competency, education, foster research, improve practice, and encourage collaboration in the forensic sciences. However, only a small number of forensic experts are members of the American Academy of Forensic Sciences.

3.11.2 Toxicology

Toxicology is the study of the effects that chemicals, such as drugs, and other substances can have. Toxicology is part chemistry, part biology, and a large part medical research. Every substance can induce some form of toxic effect. The type and nature of effects will vary depending on the dose (amount of substance that finds its way into the body), route of administration (i.e., oral, inhalation, skin, injection), duration (days, weeks, months, years), and frequency (how many times per day, week, month, year) of exposure. Properly done, examining samples of blood, urine, other bodily fluid, or tissue samples can determine whether or not an individual has used, or is currently under the influence of, a wide variety of substances.

Typically, a toxicology report will include a list of samples being tested (e.g., hair, urine, blood), the methods used for testing the samples, the patient data (including any relevant medical information such as medical conditions or prescribed medication), laboratory results which indicate which drug or chemical was tested for and whether or not the drug or chemical was present in the given toxicology sample (these results are often presented in a table or graph format), and an explanation—in simple and clear terms—that analyzes the outcomes of the findings. The nomenclature of many of these reports can be difficult for judges and juries to understand.

Pathways are the means by which an environmental chemical may reach an exposed person. Chemicals can enter the body by four fundamental routes: (1) oral exposure (e.g., ingestion of the toxic substance directly, or in food or drinking water); (2) insufflation or inhalation (e.g., breathing air or inhaling dust contaminated with the toxic substance); (3) direct contact with the skin (e.g., spilling of a pesticide mixture on the body); or (4) by direct injection into the body (e.g., introduction of a drug by intravenous injection).

Xenobiotics are substances which are foreign to human beings. Xenobiotics include therapeutic medication, alcohol and other drugs, pesticides, toxins, and other poisons. The period of detection of a xenobiotic, or its metabolite from the last exposure to the time that it is last detectable in a specimen, is critical. For example, the period of detection of alcohol in a urine sample is 7–12 hours and 1–30 days for cannabinoids. Toxicants are classified into six groups (See Table 3.11.1) based on their physical and chemical characteristics and the manner by which they are extracted (isolated) from biological fluids and tissues for analysis.

Classification of toxicants based on physicochemical properties[5]

Class of Toxicant	Examples
Toxic gases or vapors	Carbon monoxide, hydrogen sulphide, diethyl ether, chloroform
Volatile liquid poisons	Benzene, toluene, aromatic hydrocarbons, glycols, aldehydes, essential oils of some plants
Acids and strong bases	Hydrochloric or sulphuric acid, sodium or potassium hydroxide
Inorganic anions	Permanganates, chromates
Metals or salts of heavy metals	Arsenic, mercury, lead
Acids, basic or neutral non-volatile organic chemicals and drugs	Most synthetic drugs, alkaloids, illicit drugs, insecticides.

Table 3.11.1

Applications of Forensic Toxicology[6]

Sub-discipline	Purpose	Applications	Toxicants Analyzed
Postmortem toxicology	Evaluate contributing factors, cause and manner of death	• Suspected drug intoxication or overdose • Suspected poison- or drug-related death	• Drugs and their metabolites • Ethanol, toluene and other volatile substances • Carbon monoxide and other gases • Metals • Other toxic chemicals in human fluids and tissues
Human performance toxicology	Evaluate effect or impairment of human performance or behavior	• Drug-facilitated assault, rape or other crime • Suspected driving under the influence of alcohol or other drugs	• Drugs in their metabolites • Alcohol (ethanol) and other drugs • Chemicals in blood, breath or other biological specimens

Applications of Forensic Toxicology[6]

Sub-discipline	Purpose	Applications	Toxicants Analyzed
Doping control	Protect the health of athletes, maintain fair competitive standards, and prevent wagering fraud	• Use of performance-enhancing drugs in human and animal sports	• Performance-enhancing drugs • Banned substances such as stimulants, anabolic steroids and diuretics in blood or urine
Forensic drug testing	Evaluate prior use or abuse	• Use of performance-enhancing drugs in human and animal sports	• Drugs and their metabolites in urine

Table 3.11.2

What Can Go Wrong with A Toxicology Analysis?

1. Problems with sample collection, transport and storage;
2. Problems with analytical methods used (for example, random sampling is an approach in which labs test only a portion of confiscated drugs. But some state courts, such as Minnesota, disfavor random testing);[7]
3. The nature of the substance(s) present;
4. Circumstances of exposure;
5. Pharmacological factors such as tolerance, interactions or synergy.

3.11.2.1 What Toxicological Breakthroughs are Possible?

Bloodstains may soon be able to give forensic analysists a crucial piece of information-- the age of the victim. A new method devised by University at Albany chemists Kyle Doty and Igor Lednev was recently published in the American Chemical Society Journal *Central Science*.[8] Using blood from 45 donors, they were able to distinguish unique profiles from the newborns, adolescents, and adults.

It is quite amazing what medical research is doing in blood testing. Scientists have now developed a blood test for Alzheimer's disease and found that it can detect early indicators of the disease long before the first symptoms appear in patients. The blood test offers an opportunity to identify those at risk and hopefully will open new avenues in treating Alzheimer's. Western Australian researchers have reported developing a blood test that can detect early stage melanoma skin cancers. Early detection and treatment are key to curing melanoma. Phlebotomy, the process of opening a vein and collecting blood for testing and diagnosis, is regularly used to measure cells, lipids, proteins, sugars, hormones, tumor markers, and other blood components. But the results from blood tests can often take days or weeks and therein lies a challenge for the next generation of toxicological breakthroughs: can accurate results be obtained in a shorter period of time?

3.11.2.2 What Kind of Testing?

Because there are wide variations in the physical and chemical properties of xenobiotics in blood and urine, there is no universal chemical screen. Qualitative analysis detects the presence of a substance. Quantitative analysis determines the concentration of the substance. Screening tests include color tests, immunoassays, spectrophotometry, and thin layer chromatography. Confirmatory tests consist of the detection of a chemical substance by non-specific tests and must be confirmed by a second more specific technique based on a different chemical principle. As a rule of thumb, while screening tests may be cheaper and quicker, they are far less accurate than more sophisticated tests such as thin layer chromatography.

Hair analysis can be used for the determination of drug use months after drug consumption. More recently developed methods offer excellent sensitivity and can make distinction between chronic heroin and codeine use, which was not possible earlier with radioimmunoassay techniques.

3.11.3 Fiber analysis

Fiber analysis cannot actually pinpoint a suspect in an investigation since it is not as reliable as DNA. A large share of forensic science techniques involving the analysis of physical evidence have never been validated scientifically. The National Academy of Sciences concluded that, with the exception of nuclear DNA analysis, no forensic method has been rigorously shown to consistently and with a high degree of certainty demonstrate a connection between evidence and a specific individual or source and have not developed evidence-based estimates of error rates.[9] The Academy report also noted that forensic analysts are subject to "contextual bias," which occurs when the analysts are influenced by knowledge about the suspect's background or other case information.[10]

A large share of forensic science techniques involving the analysis of physical evidence have never been validated scientifically.

Forensic fiber analysis is a body of knowledge that involves laboratory testing of fiber samples found at crime scenes to determine their origin. Properly done, experts can identify the material present and link it to the same material somewhere else. ASTM, formerly known as the American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. As stated in ASTM E2225-10 – Standard Guide for Forensic Examination of Fabrics and Cordage, gaining an understanding of "the construction, composition, and color of a textile can aid the examiner in including or excluding a textile for consideration in a forensic examination."[14]

The first step of the analysis of fibers of interest is their extraction. This part of the process sounds fairly simple, but the first part of the process needs to effectively prevent contamination of the sample. ASTM E2228-10 – Standard Guide for Microscopic Examination of Textile Fibers proposes several recommended extraction methods, including tweezers, tape lifting, and gentle scraping. Tape lifts should be placed on clear uncontaminated substrate, and efforts need to be made to keep all materials clean. After extraction, fibers are examined with a stereomicroscope, with which physical features, such as crimp, length, color, relative diameter, luster, apparent cross section, damage, and adhering debris, are noted. Observations of these can help to classify the fiber samples into broader groups, such as synthetic, natural, or inorganic. Narrowing down the originating options for a fiber prevents the forensic specialists from pursuing any false conclusions. For example, one can classify a fiber as a strand of animal hair if it carries its common morphological features: the root, medulla, cortex, and cuticle. Experts can then determine the species of the animal through additional features on the hair shaft.[15]

There are no set standards, for the number and quality of character other textiles are produced using the same fiber types and color. The inability to positively associate a fiber to a particular textile to the exclusion of all others does not mean that a fiber association is without value."[16] But to repeat, fiber examiners agree, however, that none of these characteristics is suitable for individualizing fibers (associating a fiber from a crime scene with one, and only one, source) and that fiber evidence can be used only to associate a given fiber with class of fibers.[17, 18]

3.11.4 Medico-Legal Death Investigation

Half a million deaths are the subject of a medico-legal death investigations each year.[19] Medico-legal death investigation involves the scientific examination of unexplained deaths including those from homicides, suicides, blunt-force injuries, sharp-force, gunshot, and toxicological.[20] These investigations should be performed in accordance with each state's laws.[21]

There are two types of medico-legal death investigation systems, the Medical Examiner system and the Coroner system. Twenty-two states utilize a statewide medical examiner systems, with eleven others using a coroner systems, while the remaining states use a hybrid system: where some counties served by coroners, others by medical examiners, and still others a combined system where the coroner refers cases to a medical examiner.[22]

The major differences between coroners and medical examiners arise in the manner of their selection by the electorate versus appointment by the executive branch. Medical examiners also have the medical and scientific expertise required for a physical examination of the deceased, while a coroner is not required to have any medical or scientific training.[23] Coroners can be elected or appointed. Some are also sheriffs or funeral home directors. Many coroners are not doctors. There are also medical examiners, who usually are medical doctors but may not be forensic pathologists trained in death investigation. The National Academy of Sciences has criticized the lack of mandatory standards for autopsies and the absence of oversight into the performance of coroners and medical examiners. The Academy recommended that the goal of every state should be to move to hire board certified forensic pathologists and put them to work as medical examiners.[24]

Autopsies are not for the faint of heart and the description of what occurs can be disturbing to jurors. In the U.S., the predominant technique used in an autopsy involves a Y-shaped incision. The incision begins at each shoulder and extends downward, meeting the midline of the body in the lower chest, then the incision extends to the top of the pubic bone. The chest plate is removed by cutting the ribs on both sides, exposing the heart and lungs. Samples of blood, bile, urine, and eye fluid are collected. Each organ is examined, removed, weighed, photographed, and dissected. Next the heart, lungs, pancreas, spleen, liver, kidneys, prostate, and gastrointestinal tract (small and large intestines) are removed. The brain is removed by first making an incision ear to ear, reflecting the scalp and exposing the skull, then using a reciprocating bone saw to create a circular cut of the skull allowing the removal of the skullcap and the brain. Microscopic slides are made of each organ. Typically, the collected body fluids are sent to a forensic toxicologist for analysis. That analysis generates a toxicology report that lists all the compounds by type and concentration detected in the different body fluids.

Because the expertise of those who perform medico-legal death investigations varies widely, the trial judge's challenge is to determine whether their testimony is sufficient to offer expert testimony. A good example of this can be found in the case of *Verzwyvelt v.St. Paul Fire & Marine Ins. Co.*[25] Plaintiff brought suit alleging death from eating sausage meat contaminated with listeria. The coroner, had not tested specifically for the listeria bacteria, and admitted he had "little or no scientific knowledge concerning listeria, listeria infections, or the subfield of hematopathology."[26] The court allowed him to testify, as he was a forensic pathologist, but prevented him from testifying as to any opinion regarding the cause or nature of the bacterial infection that was presumably the cause of death as he was not qualified to do.[27]

3.11.5 Fire Debris / Arson, Explosion Analysis

The bombing of the Pan Am Flight 103 over Lockerbie, Scotland in 1988 created the largest crime scene in the world. It stretched for more than 1,200 square miles. By painstakingly piecing together the wreckage that was found in this area, investigators identified trace amounts of explosives that helped confirm the incident was indeed caused by a terrorist attack.

The Lockerbie explosion analysis was unique, but it illustrates what a well-funded investigation is capable of. Fire, explosion, and arson investigations examine the physical attributes of a fire or explosion. Evidence of accelerants and burn patterns may indicate criminal activity. These types of analyses can be mishandled,[28] but they can be accurate and there is support for improvement in the field. For example, the National Institute of Justice funds research to develop new and improved tools and techniques to interpret, identify, and analyze fire and explosion evidence.[29]

> *Since 1989, more than 50 people have been officially exonerated on the basis that there was no arson. However, fire debris and explosives analysis has become more reliable because of new technology.*

Fire debris and explosives analysis has become more reliable because of new technology. Advances in analytical chemistry, digital imaging, robotics, and data recording are presenting new tools and technology. For example, the development and validation of instrumentation that is capable of indicating the probability match of ignitable liquids recovered from a fire scene, to ignitable liquids on the person, or in the possession of a suspect or victim. New technology could essentially provide a DNA analysis for fire debris. Instrumentation used in other analytical areas that may have an application are: two-dimensional gas chromatography whish mass spectral detection (GC x GC/MS);

Stable Isotope Ratio Mass Spectroscopy; Gas Chromotography with tandem mass spectral detection (GC/MSn) or Fourier Transform Ion Cyclotron Resonance Mass Spectroscopy. Another area of interest is development and validation of "expert system" software for GC/MS that can rapidly compare data from case samples with a reference library of ignitable liquid standards to form probability match lists.[30]

3.11.6 Practice Pointers For Trial Judges

"Slow and painful has been man's progress from magic to law." That proverb, which is mounted at the University of Pennsylvania Law School on a statute of Hsieh-Chai, a mythological Chinese beast with the power to discern guilt, serves as an important metaphor for trial judges dealing with forensic analysis.

Can a judge safely rely on established case law regarding forensic analysis? The short answer is: maybe. The law is somewhat fixed. A trial judge can find him- or herself in a difficult spot when there is an Appellate Court decision saying one thing, and new forensic technology saying another. When this happens, judges need to be prepared for the possibility that it may be time to depart from the current state of the law.

3.11.7 A Sampling of Cases on Scientific Evidence

Forensic Analysis of Fibers

Boyd v. State 200 So.3d 685 (2015). Trial counsel was not ineffective in failing to request a Frye hearing on forensic methodologies and evidence presented. Trace and microscopic fiber analysis, forensic odontology and bite-mark analysis, and short tandem repeat (STR) DNA technology were not new nor novel at the time of trial.

People v. Prieto, 124 P.3d 842 (2005). "The court found that the fiber examination may be considered subjective because the expert examined the fibers through the filter of her own eye. However, the expert was trained in fiber analysis at the FBI, fiber analysis is subject to CBI standard operating procedures, the standard operating procedures used are accepted within the forensic community, and her test was subject to peer review. The court noted that although this expert was not going to render a conclusive opinion, her findings of consistency among the fibers might be helpful to the jury and certainly would be relevant. We conclude that the court did not err in admitting the fiber expert's testimony."

Fox v. State, 266 Ga.App. 307, 596 S.E.2d 773 (2004). Trial court did not abuse its discretion in qualifying state's witness as expert in fiber analysis. "[T]he State's expert fiber analyst had worked at the Georgia Bureau of Investigation for two years as a microanalyst in the Forensic Sciences Division, and had a bachelor of science degree in Forensic Science. She also completed a nine-month training course in the hair and fiber fields, and 'completed several oral and written tests.' Her duties included analyzing, comparing, and evaluating physical evidence including hairs, fibers, and shoeprints. She had worked on approximately 50 cases while she was employed at the GBI. Previously, she had testified as an expert in hair analysis and physical evidence, but not as a fiber expert."

3.11.8 Endnotes

1. P.L. KIRK, CRIME INVESTIGATION at 4. (Interscience Publishers, N.Y., 1953)

2. For example, the Supreme Court of Massachusetts ordered the dismissal of more than 11,000 drug convictions, as they may be tainted by the misconduct of former Massachusetts forensics chemist Sonja Farak. Farak worked in a Massachusetts drug analysis lab from 2003 until her arrest in January 2013. She served an 18-month prison sentence after being convicted of tampering with evidence, stealing illegal drugs from the facility where she worked, and cocaine possession. For six months, Farak actually overlapped at the Hinton drug lab with another disgraced Massachusetts state forensic chemist, Annie Dookhan, who was sentenced to three to five years in prison in November 2013 after admitting to mixing evidence samples and falsifying results. The Massachusetts Supreme Court directed that nearly 22,000 criminal drug cases affected by Dookhan's misconduct be overturned. That was the largest dismissal of wrongful convictions in US history.

3. BRENT TURVEY, FORENSIC FRAUD: EVALUATING LAW ENFORCEMENT AND FORENSIC SCIENCE CULTURES IN THE CONTEXT OF EXAMINER MISCONDUCT 2 (2013).

4. WILLIAM SCHWABE, ET AL., CHALLENGES AND CHOICES FOR CRIME-FIGHTING TECHNOLOGY: FEDERAL SUPPORT OF STATE AND LOCAL LAW ENFORCEMENT (2001).

5. FORENSIC TOXICOLOGY – A PRIMER FOR LAWYERS, LAWGAZETTE.COM, http://v1.lawgazette.com.sg/2016-05/1565.htm.

6. *Id*.

7. *See* State v. Robinson, 517 N.W.2d 336 (Minn. 1994) (Unless suspected drug is so homogeneously packaged as to permit extrapolating the total weight of the drug from random sample testing, the state must present evidence that all of the substance necessary to meet the minimum statutory weight was tested and identified as the suspected drug.), Alan Julian Izenman, *Statistical and Legal Aspects of the Forensic Study of Illicit Drugs*, 16 STATISTICAL SCIENCES 1 35, 36 (2001).

8. Kyle C. Doty & Igor K. Lednev, *Differentiating Donor Age Groups Based on Raman Spectroscopy of Bloodstains for Forensic Purposes*, 4 AM. CHEMICAL SOC. CENT. SCI. 7, 862-867 (2018).

9. NAT'L RES. COUNCIL, STRENGTHENING FORENSIC SCIENCE IN THE UNITED STATES: A PATH FORWARD (National Academies Press, 2009).

10. *Id*.

11. JOHN GLAISTER, HAIRS OF MAMMALIA FROM THE MEDICO-LEGAL ASPECT (1931).

12. JOHN GLAISTER, A STUDY OF HAIRS AND WOOLS BELONGING TO THE MAMMALIAN GROUP OF ANIMALS, INCLUDING A SPECIAL STUDY OF HUMAN HAIR (MISR Press, Univ. of Egypt, 1931).

13. MICROSCOPY OF HAIRS: A PRACTICAL GUIDE AND MANUAL (Univ. of Mich. Libr., 1977).

14. ASTM STANDARD E2225-10, STANDARD GUIDE FOR FORENSIC EXAMINATION OF FABRICS AND CORDAGE, (ASTM International, 2010), www.astm.org

15. Brad Kelechava, *Forensic Fiber Analysis Standards*, American National Standards Institute, (July 18, 2018) https://blog.ansi.org/?p=7140.

16. FORENSIC EXAMINATION OF FIBRES 91 (James Robertson & Michael Grieve eds., 2d ed. 1999).

17. See e.g., R.R. Bresee, *Evaluation of textile fiber evidence: A review,* 32 J. OF FORENSIC SCIENCES 2, 510-521 (March 1987), Available at https://www.researchgate.net/publication/281246146_Evaluation_of_Textile_Fiber_Evidence_A_Review, which includes the following summarization in Section 5.4: "It can never be stated with certainty that a fiber originated from a particular textile because other textiles are produced using the same fiber types and color. The inability to positively associate a fiber to a particular textile to the exclusion of all others, however, does not mean that a fiber association is without value."

    See also SWGMAT, *Introduction to forensic fiber examination*, 1 FORENSIC SCIENCE COMMUNICATIONS 1 (April, 1999).

18. NAT'L RES. COUNCIL, STRENGTHENING FORENSIC SCIENCE IN THE UNITED STATES: A PATH FORWARD, COMMITTEE ON IDENTIFYING THE NEEDS OF THE FORENSIC SCIENCES COMMUNITY 161-163 (2009).

19. RANDY HANZLICK, INST. OF MED. (US) COMMITTEE FOR THE WORKSHOP ON THE MEDICOLEGAL DEATH INVESTIGATION SYS., MEDICOLEGAL DEATH INVESTIGATION SYSTEM (2003). https://www.ncbi.nlm.nih.gov/books/NBK221926/

20. MATTHEW LUNN, ESSENTIALS OF MEDICOLEGAL DEATH INVESTIGATION (Academic Press, 2017).

21. U.S. DEP'T. OF JUST. OFF. OF JUSTICE PROGRAMS DEATH INVESTIGATION: A GUIDE FOR THE SCENE INVESTIGATOR (2011). https://abmdi.org/documents/death_investigation_guidelines.pdf

22. *Id.*; For example: Idaho, some parts of California, Colorado, Kansas, Nebraska, Nevada, some parts of New York, South Carolina, South Dakota, some areas in Texas, some parts of Washington, and Wyoming use the coroner system.

    Alaska, Alabama, Arkansas, Connecticut, Delaware, Georgia, Iowa, Kentucky, Maine, Maryland, Massachusetts, Mississippi, Montana, New Hampshire, New Jersey, New Mexico, North Carolina, North Dakota, Oklahoma, Oregon, Rhode Island, Tennessee, Utah, Vermont, Virginia, and West Virginia use the medical examiner system. Arizona and Michigan have medical examiners in each county, but they are not necessarily pathologists.

    Washington, Texas, Hawaii, Minnesota, Wisconsin, Ohio, Illinois, Pennsylvania, and New York use both the coroner and medical examiner systems. Arkansas, Kentucky, Mississippi, Montana, and North Dakota have coroners in their counties, but they also have a state medical examiner.

23. *Id*.

24. Beth Pearsall, *Improving Forensic Death Investigation,* 267 NAT'L JUST. INST. J., (Winter 2010) https://www.nij.gov/journals/267/pages/investigation.aspx

25. Verzwyvelt v. St. Paul Fire & Marine Ins. Co., 175 F. Supp. 2d 881 (W.D. La., 2001).

26. *Id*.

27. *Id*.

28. Since 1989, more than 50 people have been officially exonerated on the basis that there was no arson, according the National Registry of Exonerations. http://www.law.umich.edu/special/exoneration/Pages/about.aspx (last visited March 21, 2019).

29. NAT'L INST. OF JUST., FIRE AND ARSON INVESTIGATION (August 23, 2017), https://www.nij.gov/topics/law-enforcement/investigations/fire-arson/pages/welcome.aspx.

30. H. Tsugawa, et al., *MS-DIAL: data independent MS/MS deconvolution for comprehensive metabolome analysis* 12 NATURE METHODS 523-526, (2015); T. Pluskal, et al., MZmine 2: *Modular framework for processing, visualizing, and analyzing mass spectrometry-based molecular profile data*, 11 BMC

BIOINFORMATICS 395 (2010); S. Tanaka, et al., *Mass++: A Visualization and Analysis Tool for Mass Spectrometry*, 13 J. PROTEOMO RES., 8, 3846-3853 (2014).

3. Scientific Evidence

Section 3.12
DNA Evidence

Hon. Ming Chin

3.12.1 Introduction

As the U.S. Supreme Court has recognized, "DNA testing has an unparalleled ability both to exonerate the wrongly convicted and to identify the guilty. It has the potential to significantly improve both the criminal justice system and police investigative practices."[1] But DNA testing also raises some unique concerns. This section provides a brief overview of the legal issues resulting from the collection, testing, storage, discovery and admissibility of DNA evidence.

3.12.1.1 What is DNA?

Deoxyribonucleic acid (DNA) is a large molecule coiled up tightly inside the nucleus of most cells in the human body.[2] It comprises two complementary strands of nucleotides held together by approximately three billion base pairs. The sequence of these base pairs, considered collectively in the form of a profile, are extremely useful as a forensic identifier because of the high degree of variability among individuals.[3] About one-tenth of one percent of human DNA (about three million bases) differs from person to person, which means that the order of the bases varies on average by one base in 1,000.[4]

DNA is a type of physical evidence that helps link an offender to a crime scene.[5] The first step in forensic use of DNA is typically collecting a sample of biological material from a crime victim or a crime scene.[6] The ability to use DNA as an identifier has expanded the types of biological evidence that is useful in litigation because all biological evidence found at a crime scene can be tested for DNA.[7] Scientists identify a limited number of genetic markers in the collected sample by deploying small pieces of manufactured chemical sequences (primers) that seek out and bind to complementary DNA sequences of interest in the sample.[8] A series of primers bound to a DNA sample permits amplification of the original sample to the point that the analyst can determine a DNA "profile" for the person who was the source of the sample.[9]

The next step is to compare a DNA profile of an unknown source to a profile of a suspect or to the millions of DNA profiles stored in computer databases of law enforcement agencies throughout the country.[10] To reduce the chance of misidentification, profiles are typically based on 20 or more DNA regions, or loci, that vary from person to person.[11] A match between the profiles means that a single person could be the source of both DNA samples, a determination that is informed by the statistical rarity of the DNA profile at issue.[12] A finding of no match eliminates the known suspect as the source of the DNA collected from the victim or at the crime scene.[13]

3.12.1.2 Uses of DNA Evidence in Court

DNA evidence has been playing an important role in our legal system for some time. In criminal cases, DNA has dramatically affected questions of identity. Police, prosecutors, and defense counsel rely heavily on DNA evidence to do their jobs. Throughout the country, huge DNA databanks are being compiled with genetic information of convicted offenders, arrestees, suspects, victims and their family members, and even witnesses, for later comparison with DNA samples collected at crime scenes or from victims. These databases have enabled law enforcement authorities to make arrests in crimes that have gone unsolved for decades. Of course, DNA identity evidence may also aid the accused; all fifty states currently give inmates access to DNA evidence and testing that might not have been available at the time of trial. As of November 2018, there had been 362 post-conviction DNA exonerations in the United States.[14]

The impact of DNA evidence in criminal trials extends beyond matters of identity.

The impact of DNA evidence in criminal trials extends beyond matters of identity. In a 1998 death penalty case in Georgia, a defendant complained that his counsel conducted an inadequate mitigation defense by failing to pursue genetic testing that might have shown a genetic basis for his violent and antisocial behavior.[15] The highest state court in Georgia affirmed the death sentence, but not because it questioned this use of genetics as mitigation evidence.[16] In California, juries convicted two alcoholic lawyers in separate matters for embezzling money from clients. The attorney who claimed that a genetic disorder caused his alcoholism received a lighter sentence.[17] In another case, a jury found an accused murderer not guilty when her violence was linked to her Huntington's disease.[18]

Civil litigants also use genetic evidence in various new ways. Defendants in personal injury cases offer it on issues of both causation and damages. For example, in one toxic tort case, a chemical company whose toxins allegedly injured a child successfully sought a court order for genetic testing, hoping to establish that the child's condition was due to a genetic condition unrelated to the alleged exposure.[19] In other toxic tort cases, a defendant may offer DNA evidence of a plaintiff's genetic predisposition to a particular disease, and argue either that there was no causation — because that predisposition, not the defendant's product, caused the disease — or that damages should be reduced because the plaintiff would have developed the disease regardless of the exposure.[20] A defendant may also offer genetic evidence that the plaintiff was not exposed to the defendant's product, or does not have a susceptibility to disease as a result of the exposure, or has a particular sensitivity and was actually exposed to some other product that causes the same disease.[21] To reduce damages awarded for an exposure that causes a life-long disability, a defendant may even offer DNA evidence to show that the plaintiff, for genetic reasons, will have a shortened life.[22] Conversely, plaintiffs in toxic tort cases may offer DNA evidence on various issues, such as the fact and extent of exposure and predisposition to develop disease from a particular product.[23] This kind of evidence may be especially useful in "latent risk" cases, where plaintiffs assert they are at increased risk of developing disease in the future due to an exposure.[24] In short, genetic evidence has the potential to "transform toxic injury litigation."[25]

DNA may be introduced in civil and family law cases, not just criminal proceedings.

DNA evidence has also impacted family court judges. In family law cases, genetic evidence has traditionally been used to resolve disputes about paternity.[26] Today, it also may affect questions about parental rights. In South Carolina, for example, a judge deciding whether to terminate parental rights ordered a mother to be genetically tested for Huntington's disease.[27]

3.12.1.3 Procedures and Concerns in Handling DNA Evidence

However a litigant intends to use DNA evidence, safeguarding and preserving it is fundamental to success. Issues of admissibility may arise from the procedures followed in gathering and testing DNA evidence from a crime scene, such as the risk of contamination from incidental activity. It is important for law enforcement personnel to avoid any action that could compromise the crime scene, including smoking, eating, drinking, and littering.[28] DNA evidence is more sensitive than other types of evidence, so law enforcement personnel should be especially aware of their actions in order to prevent inadvertent contamination.[29]

Procedures for collection of DNA and chain of custody issues may affect admissibility or weight of the evidence.

Documentation about chain of custody is another critical issue for those collecting DNA evidence. For example, where laboratory analysis reveals contamination of the evidence, chain of custody records will be required for identification of those who have handled the evidence.[30] In terms of processing DNA evidence, reducing the number of people who handle the evidence will lower the risk of contamination, simplify the proof required for admission, and eliminate avenues of cross-examination that could undermine the evidence's persuasive force. To check for processing errors, many laboratories compile "a staff elimination database" containing the DNA profiles of laboratory personnel, and run test results through it to identify contaminating DNA profiles.[31] It is also good practice to note in the documentation whether the DNA evidence was found wet or dry or includes blood spatters.

Direct sunlight and warmer conditions may degrade DNA, so the best way to preserve DNA evidence is to keep it in a cold environment. Therefore, officers transporting DNA evidence, in addition to maintaining chain of custody, should avoid storing the evidence in places that may get hot, such as the trunk of a car. Any probative biological sample that has been stored dry or frozen, regardless of age, may be considered for DNA analysis. Nuclear DNA from blood and semen stains that are more than 20 years old has been analyzed successfully using polymerase chain reaction (PCR).[32] Samples that have been stored wet for an extended period may be unsuitable for DNA analysis.[33]

Some biological samples are not considered suitable for DNA testing with current techniques, including embalmed bodies (with the possible exception of bone or plucked hairs), pathology or fetal tissue samples that have been immersed in formaldehyde or formalin for more than a few hours (with the exception of pathology paraffin blocks and slides), and urine stains.[34] Other biological samples such as feces, fecal stains, and vomit can potentially be tested, but most laboratories do not routinely accept them for testing.

3.12.1.4 Data Analysis and Interpretation

After DNA evidence has been collected and properly tested, the next step is analyzing and interpreting the test results. If there is a "match" between the profile of the known individual and that of the unknown crime scene sample or the victim — meaning that the sequences in the sample from the known individual are all consistent with or present in the sequences in the unknown crime scene sample or the victim's sample — the result is considered an inclusion or non-exclusion."[35] This means that the known individual is included (cannot be excluded) as a possible source of the DNA found in the sample found at the crime or taken from the victim. Often, statistical frequencies regarding the rarity of the particular profile of genetic information observed in the unknown evidence sample and for a known individual are provided for various ethnic groups.[36] If the initial testing that produces the match involves comparison of only one or a few loci, then the possibility of including an innocent person as the source of the DNA increases, and comparison of additional loci should be done with remaining evidence. Also, there are circumstances in which a match is not legally meaningful, e.g., when the sequences are all consistent with those of the individual from whom the samples were collected (e.g., victim's sequences only on vaginal swabs taken from the victim; defendant's sequences only on a bloodstain on defendant's clothing).[37]

> *A DNA match has little significance without statistical information about the likelihood it occurred randomly.*

A match has little significance without statistical information about the likelihood it occurred randomly. The lower the likelihood the match was random, the higher the likelihood the source of the matching profile was also the source of the DNA obtained at the crime scene or from the victim. To determine the rarity of a sample's genetic profile, experts use the "product rule," which involves selecting a set of genetic markers from the sample, estimating the frequency with which each marker appears in the relevant population, and multiplying the frequencies together to produce the complete profile's frequency in the population. The resulting number may be described as the probability that the DNA of someone selected at random from the relevant population will match the DNA of the evidentiary sample.[38]

A match that results from running the DNA profile of a sample from an unknown source through a database of DNA profiles is called a "cold hit." Because these databases contain thousands, or sometimes millions, of profiles, and even unrelated people share, on average, two or three genetic markers, disputes may arise as to the significance of a cold hit. Defendants in cold hit cases sometimes challenge the use of the product rule, arguing that it fails to factor in the increased likelihood of a match that results when so many comparisons are done and thus does not accurately represent the probability of a random match. Appellate courts addressing this issue have held that, although the result of the product rule produces does not accurately express the probability of a random match in cold hit cases, it nevertheless is relevant and admissible because it accurately expresses the frequency with which a particular DNA profile appears in the general population.[39] These courts have also recognized, however, that a probability statistic reflecting the increased likelihood that a database search would produce a match may also be relevant and admissible.[40]

If testing fails to show a "match" between the profile of the known individual and that of the unknown crime scene sample or the victim — meaning that the sequences of the sample from a known individual are not all present in the sample obtained at the crime scene or from the victim — then the result is considered an exclusion, a nonmatch, or non-inclusion.[41] With limited exceptions, a nonmatch at any one loci of genetic comparison eliminates the provider of the sample as a potential source of the DNA found in the other tested sample.[42] However, in some contexts, additional testing may be necessary to make a nonmatch result meaningful, e.g., in a sexual assault case, when the suspect is excluded as the source but no samples are available from the victim and/or consensual partners.

A third possibility is that the testing is inconclusive. This can occur when the amount of DNA suitable for testing is too limited to yield more than partial results, or there are no samples from known individuals to compare with samples obtained at the crime scene or from the victim.[43]

3.12.2 DNA Databases

3.12.2.1 CODIS and NDIS

In 1990, the Federal Bureau of Investigation (FBI) started the Combined DNA Index System ("CODIS"), a pilot project to coordinate the DNA databases of 14 state and local laboratories.[44] Today, CODIS houses the National DNA Index System ("NDIS"), which allows more than 190 federal, state, and local law enforcement labs to exchange and compare DNA profiles electronically, greatly facilitating criminal investigations and searches for missing persons.[45] As of October 2018, NDIS contained over 13,566,716 offender profiles, 3,323,611 arrestee profiles, and 894,747 forensic profiles, and had produced more than 440,346 hits, assisting in more than 428,808 investigations.[46]

> *More than 190 federal, state, and local law enforcement labs exchange and compare DNA profiles electronically.*

In criminal investigations, CODIS allows an analyst at a participating lab to upload an unidentified DNA profile created from crime scene evidence and to search it against two indexes: the Convicted Offender or Arrestee Index, which contains the DNA profiles of convicted or arrested individuals, and the Forensic Index, which contains unidentified DNA profiles from other criminal investigations.[47] If a match is identified, additional steps are taken to confirm the match. If there is a confirmed match with a DNA profile stored in the Convicted Offender or Arrestee Index, then the analyst working with the unidentified DNA profile may obtain the identity of the suspect from an analyst in possession of the known DNA profile. If there is a confirmed match with a DNA profile stored in the Forensic Index, then analysts and law enforcement personnel may share information about their investigations and possibly develop new leads.

3.12.2.2 Federal Privacy, Quality Assurance, and Expungement Requirements

(i) CODIS Privacy Measures

CODIS does not store names or other personal information, so no personal information is shared before confirmation of a match.[48] At the national level, only the following is stored and may be searched for:

- the DNA profile (the set of identification characteristics or numerical representation at each of the various loci analyzed);
- the Agency Identifier of the agency that uploaded the DNA profile;
- the Specimen Identification Number (a number assigned at the time of sample collection); and,
- the DNA lab personnel associated with the DNA profile analysis.[49]

Access to DNA samples and records is generally limited to participating federal, state, and local agencies and labs, and to defendants insofar as they may access samples and analyses performed in connection with their cases.[50]

(ii) NDIS Laboratory Participation Requirements

NDIS establishes quality assurance, privacy, and expungement requirements for participating labs, including the following:[51]

- compliance with FBI Quality Assurance Standards (QAS);[52]
- external audits every two years to demonstrate compliance with the QAS;
- accreditation by a nonprofit professional association of persons actively engaged in forensic science that is nationally recognized within the forensic science community;
- limiting access to DNA samples and records in accordance with federal law.[53]

Participating states must agree, by signing a Memorandum of Understanding, to abide by the DNA Identification Act's requirements as well as other record-keeping requirements and operational procedures.[54]

(iii) NDIS DNA Data Requirements

As of December 2018, NDIS only accepted DNA data generated through the Polymerase Chain Reaction (PCR) Short Tandem Repeat (STR), Y chromosome (Y-STR), and Mitochondrial DNA (mtDNA) technologies.[55] Additional requirements include:

- DNA data has been produced by a lab that meets the laboratory participation requirements (above) and follows expungement procedures in accordance with federal law;
- DNA data fall within an acceptable NDIS category, such as convicted offender, arrestee, detainee, legal, forensic (casework), unidentified human remains, missing person, or a relative of missing person;
- DNA data meet minimum CODIS Core Loci requirements for the specimen category;
- DNA PCR data generated using PCR accepted kits.[56]

A profile of a person whose conviction has been reversed must be expunged from data bases.

(iv) NDIS Expungement Requirements

Labs must expunge profiles of convicted individuals upon receiving a certified copy of a final court order documenting reversal of the conviction. Labs must expunge profiles of arrestees upon receiving a certified copy of a final court order documenting that no charges were brought within the applicable time period or that any charges were dismissed or resulted in acquittal.[57]

(v) FBI Quality Assurance Standards (QAS)

The FBI's QAS describe the minimum standards for labs performing DNA analysis and/or databasing, and cover the following areas: organization, personnel, facilities, evidence or sample control, validation, analytical procedures, equipment calibration and maintenance, reports, review, proficiency testing, corrective action, audits, safety, and outsourcing.[58]

3.12.2.3 Local Databases

Police investigators increasingly rely on their own local DNA databases instead of the FBI's national DNA database network, because of federal restrictions regarding CODIS and NDIS.[59] These local databases largely operate outside of federal regulation, so they are not limited to convicted offenders and arrestees; they often also contain DNA profiles of suspects, victims and their family members, witnesses, and abandoned biological material.[60] Use of these local databases is controversial. Supporters argue that the practice "allows police to maximize the potential of genetic surveillance to solve crimes,"[61] but critics assert that it "has unleashed significant negative forces that threaten privacy and dignity interests, exacerbate racial inequities in the criminal justice system, and undermine the legitimacy of law enforcement."[62]

3.12.3 Fourth Amendment Issues

The Fourth Amendment to the United States Constitution protects the right to be free from "unreasonable" government "searches and seizures."[63] According to U.S. Supreme Court decisions, a search occurs when the government intrudes upon a reasonable expectation of privacy;[64] a seizure of property occurs when the government meaningfully interferes with a possessory interest;[65] and, a seizure of a person occurs when freedom of movement is restrained by means of physical force or show of authority, and a reasonable person would believe he or she was not free to leave.[66] A warrant supported by probable cause is generally required for a search or seizure, but there are exceptions to this requirement "because the ultimate touchstone of the Fourth Amendment is 'reasonableness'."[67] This section provides an introduction to some of the Fourth Amendment issues that arise in connection with collecting biological samples for DNA testing and creating, storing, and comparing DNA profiles.

3.12.3.1 Collecting Biological Samples for DNA Testing

(i) Collecting Biological Samples from a Person's Body without Consent

The U.S. Supreme Court has recognized that an "intrusion into the human body" by the government—such as swabbing the inside of a cheek, scraping fingernails, or withdrawing blood—constitutes a Fourth Amendment search.[68] Thus, without a warrant supported by probable cause, law enforcement officers generally may not collect a biological sample without consent.

> *Taking a DNA sample is a search for Fourth Amendment purposes.*

The analysis changes, however, upon a person's arrest for or conviction of a serious crime. For example, the U.S. Supreme Court has held that when law enforcement officers, after making an arrest supported by probable cause for a serious offense, bring the arrestee to the station for custodial detention, they may swab the inside of the arrestee's cheek to collect an evidentiary sample for DNA testing.[69] The reasonableness of this "legitimate police booking procedure" is established by the government's significant interests in identifying persons taken into custody and solving crimes, the unique effectiveness of DNA identification, the minimal intrusion of a cheek swab, and the reduced privacy expectation of those in police custody.[70] Likewise, the government may, without a warrant and without consent, collect evidentiary samples for DNA testing from those convicted of felony crimes.[71]

(ii) Collecting Biological Samples from a Person's Body with Consent

Consent allows law enforcement officers to conduct a search and/or make a seizure without a warrant and without probable cause, provided that the consent is voluntarily given[72] and the search and/or seizure does not exceed the scope of consent.[73] Consent is "voluntarily given" when, under the totality of the circumstances, it is "not the result of duress or coercion, express or implied."[74] The scope of consent is determined by asking what a reasonable person—knowing what the officer knew at the time—would have understood the individual to have consented to.[75] Both the voluntariness and the scope of consent are questions of fact entitled to deference upon appeal.

When a person provides a biological sample in cooperation with a law enforcement investigation, unique concerns may arise about the scope of consent. First, the person may not have known, at the time of consent, that the government would use the sample for DNA testing. This issue may arise because today's technology allows DNA analysis on samples that were taken before DNA testing was even available. When faced with this issue, an appellate court in Connecticut concluded that, because the defendant had consented to "a complete search" of his saliva samples without limiting when or how they could be tested, DNA tests performed over 20 years later did not exceed the scope of his consent. "[A] reasonably objective person," the court reasoned, "would understand that the police obtained the saliva sample with the intention of determining who committed the victim's murder and that they would continue their search until they found the person responsible."[76]

Second, the person providing the sample may not know that the government intends to use the resulting DNA profile in other law enforcement investigations. In a Maryland case presenting this issue, the appellate court concluded that, because the defendant signed a consent form acknowledging that "any evidence found to be involved in this investigation … can be used in any future criminal prosecution," running his DNA profile through state and county DNA databases, after testing showed he was the source of DNA collected in the case under investigation, did not exceed the scope of his consent.[77]

Cases like these suggest that when someone provides a biological sample for use in an investigation without expressly limiting the scope of consent, officers may use the sample for DNA testing and may use the resulting DNA profile in connection with other investigations.[78]

(iii) Collecting Biological Samples from Items Lawfully in Government Custody

Collecting biological samples for DNA testing from items lawfully in the government's possession generally does not constitute a search.[79] One court has held, however, that when law enforcement officers have an item from the victim of one crime, and they suspect that the victim committed an unrelated crime, they need a warrant to collect a DNA sample from the item.[80]

(iv) Collecting "Abandoned" Biological Samples

The U.S. Supreme Court has held that there is no reasonable expectation of privacy in items abandoned in public.[81] This rule has been applied in cases where individuals have "abandoned" their biological material—or an item containing their biological material—in public.[82] Therefore, law enforcement officers do not need probable cause or a warrant to collect DNA from abandoned genetic material such as a straw, cup or cigarette.

3.12.3.2 Creating a DNA Profile from Lawfully Obtained Biological Samples

The U.S. Supreme Court has stated that the collection of biological material and subsequent forensic analysis of that material constitute separate Fourth Amendment searches.[83] But it has also held that, given the limited genetic information sought and revealed by the loci involved in identity testing, analysis of DNA that has been lawfully collected does "not amount to a significant invasion of privacy that would render the DNA identification impermissible under the Fourth Amendment."[84] At least one court has held, however, that the government needs a warrant to create a DNA profile from a victim's DNA sample where the government suspects that the victim committed an unrelated crime.[85]

3.12.3.3 Storing and Comparing DNA Profiles

Courts generally hold that retaining a DNA profile and comparing it to the profiles of later collected DNA samples does not constitute a Fourth Amendment search.[86] But Fourth Amendment concerns may arise when the government continues to store and use the DNA profiles of convicted persons after they have completed their sentences and any terms of parole or probation,[87] or of arrestees if no charges are brought within the required time period or after the charges have been dismissed or resulted in acquittal.[88]

3.12.3.4 Familial testing

A relatively new, but controversial, technique is familial database searching, which uses DNA to identify criminals through their relatives.[89] Investigators search databases for DNA profiles that closely resemble, but do not exactly match, the profile of DNA that an unidentified suspect left behind at the crime scene.[90] This technique is based on the scientific fact that a person's DNA is much more similar to the DNA of the person's biological relatives than to the DNA of unrelated persons.[91] Because of this fact, a partial match may, depending on its degree, suggest that the source of the DNA at the crime scene is a biological relative of the person identified from the database search.[92] Police can interview that person's relatives, hoping to identify and find the suspect.[93] Some claim that use of this technique could increase the yield of investigative leads by 40%.[94] The United Kingdom has been doing familial database searching since 2002, and has used it to solve several sensational crimes.[95] Maryland and the District of Columbia prohibit the technique, but as of 2018, ten states use it.[96]

The use of familial data bases are prohibited in Maryland and the District of Columbia.

Critics of this technique argue that it puts all family members under "genetic surveillance" for crimes they are not even alleged to have committed.[97] Others argue that "it turns family members into genetic informants without their knowledge or consent."[98] Some legal scholars assert that a familial database search constitutes an unreasonable, and therefore unconstitutional, search.[99] In a 2010 decision, a federal appellate court noted that the government's use of CODIS to discover partial matches "[a]rguably" raises unique "privacy concerns."[100] One constitutional law professor has warned that "if familial searching proceeds, it will create a political firestorm."[101] Because of such concerns, the FBI has so far declined to pursue familial database searching.[102]

In a related technique, investigators are using commercial, publicly available genealogical/ancestry websites (such as Ancestry and 23 and Me) to search for genetic relatives of the unidentified person who is the source of DNA found at a crime scene. Through this technique, detectives in California recently arrested a 72-year-old man whom they believe committed a string of rapes and murders in the 1970s and 1980s.[103] They submitted DNA leftover from some of those decades-old crimes to a commercial ancestry website and identified the suspect's great-great-great grandparents. They then constructed about 25 distinct family trees of their descendants, located two descendants who were about the suspect's age and had ties to the locations of the crimes, surveilled one of those descendants, recovered an item he discarded, and performed DNA testing on the discarded item. The testing produced a match between DNA on the discarded item and DNA recovered at one of the crime scenes.[104]

In a criminal case, the statute of limitations does not begin to run until the DNA match occurs.

3.12.4 Procedural Issues

3.12.4.1 Statutes of Limitations

In the criminal context, statutes of limitations limit the time period within which the government may file charges for criminal conduct. They primarily reflect a legislative judgment that at some point, the benefits of prosecuting an old crime are outweighed by the costs, primarily due to concern about the defendant's inability to obtain sufficient and accurate evidence for a defense.[105] Under the general statute of limitations for federal crimes, the government must file charges within five years of the offense.[106] There are several exceptions to this statute, however, including for capital offenses, terrorism, white collar crimes, and crimes against children.[107]

Many legislatures, in recognition of the accuracy and reliability of DNA testing, have created special exceptions to statutes of limitations for cases that may be solved with such testing.[108] Under federal law, if DNA testing implicates a known person in the commission of a felony, then "no statute of limitations . . . shall preclude such prosecution until a period of time following the implication of the person by DNA testing has elapsed that is equal to the otherwise applicable limitation period."[109] In other words, the statute of limitations does not begin to run until the DNA match occurs.[110]

3.12.4.2 Doe Warrants and Indictments

Under federal law, if the DNA profile of an unidentified source implicates the source in a crime of sexual abuse, then the government may file an indictment against an "individual whose name is unknown, but who has a particular DNA profile" to effectively toll the statute of limitations.[111] At least one court has held that DNA-based "John Doe" indictments do not violate a defendant's constitutional right to notice.[112]

Likewise, several states authorize the filing of an arrest warrant based on an unidentified suspect's DNA profile, which allows prosecution to commence before the statute of limitations expires. The hope is that the suspect will later be identified through a DNA match. Provided that the DNA profile is sufficiently discriminating, state courts have upheld these DNA-based "John Doe" arrest warrants against federal and state constitutional challenges, including arguments that they violate the Fourth Amendment's particularity requirement and the Sixth Amendment's notice requirement.[113]

3.12.4.3 Pre-Indictment Delay

Even if a prosecution does not violate the applicable statute of limitations, the U.S. Supreme Court has stated that the Due Process Clause may require dismissal of charges upon a showing that an unreasonable prosecutorial delay actually prejudiced the defendant's right to a fair trial.[114] The high court has clarified, however, that unlike pre-indictment delay "to gain tactical advantage over the accused," "investigative delay does not deprive [a defendant] of due process, even if his defense might have been somewhat prejudiced by the lapse of time."[115] Consequently, claims of unreasonable prosecutorial delay have failed where the pre-indictment delay was due to DNA testing, such as when a defendant's DNA profile matches a stored DNA profile from crime scene evidence years after the crime was committed.[116]

3.12.5 Discovery Issues

3.12.5.1 Brady Duty to Disclose Material Exculpatory DNA Evidence and Information

In *Brady v. Maryland*, the U.S. Supreme Court held that the Due Process Clause of the Fourteenth Amendment requires the prosecution to disclose to the defense all material exculpatory evidence and information in the government's possession.[117] Courts have made clear that this *Brady* duty includes evidence and information possessed by the government's crime lab.[118]

Therefore, the government has a *Brady* duty to disclose any material exculpatory DNA evidence and any material exculpatory information about collection, testing, and storing of DNA evidence. This might include: flaws in the collection process or chain of custody; prior incidents of lab error; failed proficiency tests by lab technicians or analysts; inconclusive results; evidence of contamination; and DNA evidence from other crimes that might exonerate the accused in the case at hand.[119]

Brady requires disclosure of any material exculpatory DNA evidence.

The U.S. Supreme Court has also held, however, that *Brady* does not require the government to provide convicted defendants with access to the government's evidence so they may subject it to DNA testing.[120] In doing so, the high court noted that the federal government and forty-six States had already enacted statutes dealing with post-conviction access to DNA evidence.[121]

3.12.5.2 Government's Duty to Preserve Biological Evidence for Later Testing

In *California v. Trombetta*, the U.S. Supreme Court held that the that the Due Process Clause of the Fourteenth Amendments requires the government to preserve material exculpatory evidence "of such a nature that the defendant would be unable to obtain comparable evidence by other reasonably available means."[122] Later, in *Arizona v. Youngblood*, the court clarified that unless the defendant can "show bad faith on the part of the police, failure to preserve potentially useful evidence does not constitute a denial of due process of law."[123]

Therefore, the government has a constitutional duty not to destroy any material exculpatory DNA evidence or any material exculpatory information about collection, testing, and storing of DNA evidence that the defendant may not obtain by other reasonably available means, but its failure to carry out this duty violates due process only if it acts in bad faith. Accordingly, courts have held that when government DNA testing would consume an evidentiary sample, the government is not required split the sample with the defense.[124]

3.12.5.3 Discovery in Criminal Cases Involving a NDIS DNA Match

In cases involving DNA matches through NDIS, criminal defendants are entitled to access the DNA samples and analyses that were performed in connection with their cases.[125] The "hit file" of the U.S. Department of Justice's DNA Data Bank Program generally includes:

- the hit notification letter that was issued by the database administrator to the DNA casework lab, including the name and state identification number of the offender whom the evidence profile matched;
- the specimen match detail report, specifying how many loci the profiles have in common and at which stringency;
- a photocopy of the offender's sample submission card that was submitted with the offender's buccal sample;
- chain of custody information, including the chronology of testing process;
- electropherograms for both the original and confirmation analyses;[126]
- procedural check sheets; and
- documentation of the technical and administrative review process.[127]

3.12.5.4 Discovery in Criminal Cases Involving DNA Evidence

Discovery is particularly important in cases involving DNA evidence because it may reveal concerns about the evidence's collection, transportation, storage, and testing. This section provides a brief overview of the items that are discoverable in most cases.

Rule 16 of the Federal Rules of Criminal Procedure establishes for prosecutors three disclosure responsibilities that may be relevant to forensic evidence:

1. the prosecution must permit a defendant to inspect and copy any results or reports of a scientific test that are (i) in the government's possession, custody or control, (ii) known or through due diligence could be known to a government attorney, and (iii) material to preparing the defense or intended to be used by the government in its case in chief at trial (rule 16(a)(1)(F));
2. the prosecution must provide, upon request, a written summary of any expert testimony the government intends to use during its case in chief at trial, including the expert's opinions, the bases and reasons for those opinions, and the expert's qualifications (rule 16(a)(1)(G)); and,
3. the government must produce, upon request, documents and items material to preparing the defense that are in the possession, custody, or control of the government, which may include records documenting the tests performed, the maintenance and reliability of tools used to perform those tests, and/or the methodologies employed in those tests (rule 16(a)(1)(E)).

Separately, the Quality Assurance Standards for Forensic DNA Testing Laboratories require participating labs to keep extensive records, which are subject to discovery.[128] For example, under Standard 11.2, a lab report must contain the following:

- case identifier;
- description of evidence examined;

- a description of the technology;
- locus or amplification system;
- results and/or conclusions;
- quantitative or qualitative interpretative statement;
- date issued;
- disposition of evidence; and,
- signature and title, or equivalent identification, of the person accepting responsibility for the content of the report.

Other required items that are subject to discovery include:

- documentation of the lab's quality system manual (Standard 3)
- documentation of the lab's evidence control system (Standard 7)
- documentation of the lab's standard operation procedures (Standard 9)
- records of proficiency testing (Standard 13); and,
- documentation regarding corrective action when casework errors are detected (Standard 14).

Finally, chain-of-custody records, which document all transfers of DNA evidence—from collection to testing to the courtroom—are also discoverable. At a minimum, these records should include the locations where the evidence was stored and the names of anyone who had custody of the evidence, including those who:

- collected the evidence;
- sent and received the evidence to and from the police department and/or the lab;
- transported the evidence to and from the police department and/or the lab;
- logged evidence into and out of the evidence room.

3.12.6 Admissibility Issues

3.12.6.1 Expert Testimony based on DNA Evidence: Frye[129] and Daubert[130]

An extensive discussion on these cases is found in *Section 7* in this Bench Book.

3.12.6.2 Confrontation Clause Issues

The Confrontation Clause of the Sixth Amendment to the U.S. Constitution affords criminal defendants the right to cross-examine witnesses who offer testimony that serves as substantive evidence against them.[131] In *Crawford v. Washington*, the U.S. Supreme Court held that "[t]estimonial statements of witnesses absent from trial [may be] admitted only where the declarant is unavailable, and only where the defendant has had a prior opportunity to cross-examine."[132] This holding raises two questions: whether DNA reports constitute "testimonial" evidence and whether the defendant has a right to cross-examine the analysts involved in production of the DNA report.

Crawford described "testimonial" evidence as "ex parte in-court testimony or its functional equivalent," such as "affidavits, custodial examinations, prior testimony that the defendant was unable to cross-examine, or similar pretrial statements that declarants would reasonably expect to be used prosecutorially."[133] Importantly, *Crawford* suggested that business records were not testimonial.[134] In *Melendez-Diaz v. Massachusetts* (2008) 557 U.S. 305, and *Bullcoming v. New Mexico*, 564 U.S. 647 (2011), the U.S. Supreme Court held that a lab's sworn affidavit identifying as cocaine a substance seized from the defendant and a lab's blood alcohol concentration (BAC) report of the alcohol content in a sample of defendant's blood were testimonial evidence for purposes of the Confrontation Clause.[135] Together, these decisions hold that if a scientific report and its conclusions are offered for the truth of the matters they assert, as substantive evidence against a defendant, the analysts involved in the subject of the report are subject to confrontation.

In *Williams v. Illinois*, however, a divided U.S, Supreme Court held that an expert witness's testimony about a non-admitted DNA report prepared by a non-testifying analyst did not violate the Confrontation Clause.[136] In that case, during the defendant's trial for rape, one of the prosecution's expert witnesses testified that she had matched two DNA profiles: one produced by another testifying analyst from a sample of defendant's blood, and another produced by a non-testifying analyst at an outside lab. The trial court excluded the outside lab report in response to the defendant's objection that it had shown that the DNA profile provided by the outside lab was produced from semen found on vaginal swabs taken from the victim. Justice Alito, writing for a four-justice plurality, provided two, independent grounds for finding no constitutional violation. First, the testimony at issue was not admitted to prove the truth of the matters asserted, i.e., that the outside lab's report had shown that the DNA profile provided by the outside lab was produced from semen found on vaginal swabs taken from the victim.[137] Rather, it was offered to explain the basis for the expert's conclusion that the DNA profile produced from a sample of the defendant's blood matched the DNA profile provided by the outside lab.[138] Second, even if the other lab's report had been introduced for its truth, it would not constitute "testimonial" evidence for purposes of the Confrontation Clause, because unlike the forensic reports prepared in *Melendez-Diaz* and *Bullcoming*, it was not prepared for the primary purpose of creating evidence to use at trial to prove the guilt of a particular criminal defendant.[139] To this end, the plurality noted that lab technicians preparing DNA profiles "generally have no way of knowing whether it will turn out to be incriminating or exonerating--or both."[140]

Justice Thomas, writing only for himself, agreed with the plurality that the expert's statements were non-testimonial; in his view, the lab's report lacked the requisite "formality and solemnity."[141] Meanwhile, he agreed with the dissent that the expert's statements were offered for their truth and "share[d] the dissent's view of the plurality's flawed analysis."[142]

Therefore, it is unclear whether the prosecution is required call the analysts involved in the production of a DNA report in order to introduce it and its conclusions as substantive evidence against a defendant. In a recent dissent to a denial of certiorari, Justice Gorsuch, joined by Justice Sotomayor, noted, "This Court's most recent foray in this field, *Williams v. Illinois*, yielded no majority and its various opinions have sown confusion in courts across the country."[143]

3.12.6.3 Prejudice Concerns

(i) Presenting Evidence of DNA Database Matches

Under Federal Rule of Evidence 404(b), evidence of a "crime, wrong, or other act" is not admissible to prove a person's character in order to show that the person acted in accordance with that character on a particular occasion; but such evidence may be admitted for another, non-propensity purpose.

Concerns may arise when the prosecution presents evidence that a DNA profile created from crime scene evidence was matched to a defendant's DNA profile in a DNA database. From the fact that the defendant's DNA profile was stored in a DNA database, jurors may infer that the defendant was previously arrested or convicted of a crime and, therefore, has a propensity to engage in criminal conduct. Consequently, defense counsel have moved to suppress such evidence under rule 404(b) and its state equivalents.

Courts have rejected these motions on the ground that the evidence was introduced, not to show propensity, but to explain how the defendant became the suspect in the case and to avoid juror confusion.[144] It may be appropriate, however, for the trial court to issue a limiting instruction:

1. to prevent the prosecution from suggesting that the defendant's DNA profile was in the DNA database as the result of prior criminal activity, and/or
2. to require the prosecution to elicit testimony that the DNA database contains DNA profiles from individuals who were not arrested or convicted of a crime.[145]

(ii) Presenting Evidence of Inconclusive DNA Test Results

Under Federal Rule of Evidence Rule 403, evidence that is relevant and otherwise admissible may be excluded if its probative value is substantially outweighed by a risk of unfair prejudice and/or misleading the jury. Such risks arise when DNA test results leave questions as to whether the defendant truly was the source of the DNA evidence—for example, when the defendant may not be excluded as a suspect, when there is a relatively low statistical probability that the defendant contributed to the sample, or a relatively high statistical probability of a random match.

Generally, courts have found that such DNA test results are admissible, because their probative value is not substantially outweighed by their potential to cause unfair prejudice to the defendant or to confuse the jury.[146] In these cases, courts have stressed the "ameliorative potential of cross-examination, counter-experts, and clarifying jury instructions."[147] But at least one court has reversed where inconclusive DNA test results were admitted without accompanying testimony explaining the statistical relevance of the results.[148]

3.12.7 Endnotes

1. District Attorney's Office for Third Judicial Dist. v. Osborne, 557 U.S. 52, 55 (2009).

2. MING W. CHIN ET AL., FORENSIC DNA EVIDENCE: SCIENCE AND THE LAW § 2.2 (The Rutter Group 2017).

3. *Id*.

4. *Id*. §1.1.

5. National Institute of Justice, *DNA Evidence: Basics of Identifying, Gathering and Transporting*, https://www.nij.gov/topics/forensics/evidence/dna/basics/pages/identifying-to-transporting.aspx (last visited Dec. 13, 2018).

6. CHIN ET AL., *supra* note 2, at § 1.1.

7. National Institute of Justice, *DNA Evidence: Basics of Identifying, Gathering and Transporting*, https://www.nij.gov/topics/forensics/evidence/dna/basics/pages/identifying-to-transporting.aspx (last visited Dec. 13, 2018).

8. CHIN ET AL., *supra* note 2, at § 1.1.

9. *Id*.

10. *Id*.

11. Before 2017, the FBI required that most profiles include 13 loci for inclusion its database. Effective January 1, 2017, the FBI increased the number of required loci to 20. (FBI, *Frequently Asked Questions on CODIS and NDIS*, https://www.fbi.gov/services/laboratory/biometric-analysis/codis/codis-and-ndis-fact-sheet (last visited Dec. 18, 2018)

12. CHIN ET AL., *supra* note 2 at § 2.3

13. *Id*. at § 1.1

14. Innocence Project, *Fast Facts: DNA Exonerations in the United States*, https://www.innocenceproject.org/dna-exonerations-in-the-united-states/ (last visited Nov. 15, 2018).

15. Turpin v. Mobley, 502 S.E.2d 458 (Ga. 1998).

16. *Id*. at 466-467.

17. CHIN ET AL., *supra* note 2 at § 13.10.

18. *Id*.
19. Lori B. Andrews, *Genetics, Reproduction, and the Law*, 35 TRIAL 7 (July 1999).
20. Gary E. Marchant, *Genetic Susceptibility and Biomarkers in Toxic Injury Litigation*, 41 JURIMETRICS JOURNAL 67, 68 (2000).
21. *Id*.
22. *Id*. at 101.
23. *Id*. at 68.
24. *Id*. at 84.
25. *Id*. at 68-69.
26. CHIN ET AL., *supra* note 2 at § 13.10.
27. *Id*.
28. National Institute of Justice, *DNA Evidence: Basics of Identifying, Gathering and Transporting*, https://www.nij.gov/topics/forensics/evidence/dna/basics/pages/identifying-to-transporting.aspx (last visited Dec. 13, 2018).
29. *Id*.
30. *Id*.
31. Mary McCarthy, *Am I My Brother's Keeper?: Familial DNA Searches in the Twenty-First Century*, 86 Notre Dame L. Rev. 381, 392 (2011).
32. *Id*.
33. *Id*.
34. *Id*.
35. *Id*.
36. *Id*.
37. *Id*.
38. People v. Nelson, 43 Cal. 4th 1242 (Cal. 2008).
39. *Id*.; *See also* U.S. v. Jenkins, 887 A.2d 1013 (App. D.C. 2005)
40. *Id*.

41. *Id*.

42. *Id*.

43. *Id*.

44. *Combined DNA Index System (CODIS)*, FED. BUREAU OF INVESTIGATION, CRIM. JUST. INFO. SERV. (Dec. 5, 2018), https://www.fbi.gov/services/laboratory/biometric-analysis/codis (last visited Dec. 13, 2018).

45. *CODIS and NDIS Factsheet*, FED. BUREAU OF INVESTIGATION, CRIM. JUST. INFO. SERV. (Dec. 5, 2018), https://www.fbi.gov/services/laboratory/biometric-analysis/codis/codis-and-ndis-fact-sheet (last visited Dec. 13, 2018).

46. FED. BUREAU OF INVESTIGATION, CRIM. JUST. INFO. SERV., *CODIS - NDIS Statistics*, (Dec. 5, 2018), https://www.fbi.gov/services/laboratory/biometric-analysis/codis/ndis-statistics (last visited Dec. 13, 2018)

47. *CODIS and NDIS Factsheet*, supra note 43.

48. *Id*.

49. *Id*.

50. 34 U.S.C. § 12592 (b)(3) (situations in which DNA samples and DNA analyses may be disclosed).

51. 42 U.S.C. § 14132(b).

52. See FED. BUREAU OF INVESTIGATION, QUALITY ASSURANCE STANDARDS FOR FORENSIC TESTING LABORATORIES (2011) [hereafter *QAS for Forensic Testing Laboratories*] (available at https://www.fbi.gov/file-repository/quality-assurance-standards-for-forensic-dna-testing-laboratories.pdf/view); FED. BUREAU OF INVESTIGATION, QUALITY ASSURANCE STANDARDS FOR DNA DATABASING LABORATORIES (2011) [hereafter *QAS for DNA Databasing Laboratories*] (available at https://www.fbi.gov/file-repository/quality-assurance-standards-for-dna-databasing-laboratories.pdf/view).

53. *CODIS and NDIS Factsheet*, supra note 43.

54. *Id*.

55. *Id*.

56. *Id*.

57. *Id*.

58. See *QAS for Forensic Testing Laboratories and QAS for DNA Databasing Laboratories*, *supra* note 50.

59. Jason Kreag, Going Local: The Fragmentation of Genetic Surveillance, 95 B.U.L.Rev. 1491, 1492-1494 (Oct. 2015).

60. *Id*. at 1497, 1499.

61. *Id*. at 1496.

62. *Id*. at 1493.

63. U.S. CONST. Amend. IV ("The right of the people to be secure in their persons, houses, papers, and effects, against unreasonable searches and seizures, shall not be violated . . . ").

64. U.S. v. Katz, 389 U.S. 347 (1967).

65. U.S. v. Jacobsen, 466 U.S. 109 (1987).

66. U.S. v. Mendenhall, 446 U.S. 544, 553-54 (1980).

67. Brigham City v. Stuart, 547 U.S. 398, 403 (2006).

68. Maryland v. King, 569 U.S. 435, 446 (2013) (collecting cases).

69. *Id*. at 465-66.

70. *Id*. at 461-62, 465.

71. *See id*. at 445 (noting that all 50 states require the collection of DNA from felony convicts).

72. Schneckloth v. Bustamonte, 412 U.S. 218 (1973).

73. Florida v. Jimeno, 500 U.S. 248 (1991).

74. *Schneckloth*, 412 U.S. at 248.

75. *Jimeno*, 500 U.S. at 251.

76. State v. Benefield, 103 A.3d 990, 1000 (Conn. App. 2014).

77. Varriale v. State, 119 A.3d 924 (Md. App. 2015).

78. *See* People v. Collins, 250 P.3d 668 (Colo. App. 2010), *cert. denied* No. 10SC223, 2010 WL 4400041 (Colo. 2010) (Colorado's matching of DNA sample from victim's rape kit to defendant's DNA profile did not exceed scope of consent where

defendant provided saliva sample in connection with robbery investigation in Missouri and then Missouri police sent defendant's DNA profile to Denver police because defendant did not place express limitation on his consent); Com. v. Gaynor, 820 N.E.2d 233 (Mass. 2005) (DNA testing did not exceed scope of consent where defendant provided blood sample with the understanding that it would only be used in comparison with blood samples from one crime scene and did not place explicit limitation on his consent); Pace v. State, 524 S.E.2d 490 (Ga. 1999), *cert. denied* 531 U.S. 839 (2000) (use of DNA profile in four separate investigations did not exceed scope of consent where defendant provided blood sample pursuant to consent form stating "for further use in this particular investigation" because defendant did not place explicit limitation on his consent). *But see* State v. Gerace, 437 S.E.2d 862 (Ga. App. 1993) (DNA testing exceeded scope of consent where defendant provided blood sample pursuant to implied consent law that limits the scope of implied consent to "determining alcohol or drug content").

79. Com. v. Arzola, 26 N.E.3d 185 (Mass. 2015), *cert. den*. 136 S.Ct. 792 (2016) (collecting unknown DNA sample from arrestee's item lawfully in government custody).

80. U.S v. Davis, 690 F.3d 226 (4th Cir. 2012), *cert. den*. 571 U.S. 829 (2013).

81. California v. Greenwood, 486 U.S. 35 (1988).

82. Williamson v. State, 993 A.2d 626, 633-637 (Md. App.2010), *cert. denied*, 131 S. Ct. 419 (2010) (collecting DNA sample from pretrial detainee's saliva on McDonald's cup that he left on the floor of his jail cell); Com. v. Perkins, 883 N.E.2d 230 (Mass. 2008) (collecting DNA samples from suspect's saliva on two cigarette butts and a soda can that he left behind in interrogation room of police station after a voluntary interview); State v. Athan, 158 P.3d 27 (Wash. 2007) (en banc) (collecting DNA sample from suspect's saliva on envelope sent by suspect to police officers posing as class action lawyers).

83. *See* Skinner v. Railway Labor Executives' Ass'n, 489 U.S. 602, 619 (1989) ("[T]he collection and subsequent analysis of the requisite biological samples must be deemed Fourth Amendment searches").

84. Maryland v. King, 569 U.S. 435, 465 (2013)

85. *Davis*, 690 F.3d 226.

86. Boroian v. Mueller, 616 F.3d 60, 67–68 (1st Cir. 2010) (collecting authority in support of this proposition).

87. Compare U.S. v. Kincade, 379 F.3d 813, 841-42 (9th Cir. 2004), cert. den. 379 F.3d 813 (2005) (noting that individuals who have "wholly cleared their debt to society" have "substantial privacy interest at stake") with Johnson v. Quander, 440 F.3d 489, 498-500 (D.C. Cir. 2006), *cert. den*. 127 S.Ct. 103 (2006) (rejecting argument that an individual's reasonable expectation of privacy in his DNA sample is restored upon completion of probation).

88. *See* State v. Blea, 425 P.3d 385, 393 (N.M. Ct. App. 2018) [rejecting claim that placing burden on arrestees to seek expungement violates the Fourth Amendment]; People v. Buza, 4 Cal. 5th 658, 680-681 [noting, but not addressing, potential Fourth Amendment issues with California's failure to provide for automatic expungement where charges do not result in felony conviction or convictions are overturned]; Center For Genetics and Society et al. v. Becerra et al., CPF-18-516440, filed Dec. 10, 2018, in San Francisco Superior Court [asserting that California's expungement procedures violate state constitutional right of privacy and prohibition against unreasonable searches and seizures].)

89. Maura Dolan & Jason Felch, *California Takes Lead on DNA Crime-Fighting Technique*, https://www.geneticsandsociety.org/article/california-takes-lead-dna-crime-fighting-technique (last visited December 27, 2018).

90. *Id*.

91. Religion & Ethics NewsWeekly, *Familial DNA Testing* https://www.pbs.org/wnet/religionandethics/2008/05/16/march-6-2009-familial-dna-testing/66/ (last visited Dec. 13, 2018)

92. *Id*.

93. *Id*.

94. *Id*.

95. *Id*.

96. *Id*.

97. *Id*.

98. Ellen Nakashima, *From DNA of Family, a Tool to Make Arrests*, Wash. Post, Apr. 21, 2008, at A01 (last visited Dec. 13, 2018) http://www.washingtonpost.com/wp-dyn/content/article/2008/04/20/AR2008042002388_pf.html; *see generally* Sonia M. Suter, All in the Family: Privacy and DNA Familial Searching, 23 Harv. J.L. &

Tech. 309 (2010) (arguing familial searching should proceed with caution because it implicates significant privacy concerns).

99. Dolan & Felch, *supra*, note 84.

100. Boroian v. Mueller, 616 F.3d 60, 69 (1st Cir. 2010).

101. *Id*.

102. Nakashima, *supra*, note 93.

103. Joseph James DeAngelo, the so-called Golden State Killer.

104. Justin Jouvenal, *To Find Alleged Golden State Killer, Investigators First Found His Great-great-great-Grandparents*, WASH. POST, (Apr. 30, 2018) https://www.washingtonpost.com/local/public-safety/to-find-alleged-golden-state-killer-investigators-first-found-his-great-great-great-grandparents/2018/04/30/3c865fe7-dfcc-4a0e-b6b2-0bec548d501f_story.html?utm_term=.92432f4d9eb9

105. *See* Stogner v. California, 539 U.S. 607, 615-16 (2003).

106. 18 U.S.C. § 3282(a).

107. *See* 18 U.S.C. §§ 3281 (capital offenses), 3283 (child abuse and kidnapping); 3286 (terrorism).

108. *See e.g.*, 18 U.S.C. §§ 3282(b), 3297.

109. 18 U.S.C. § 3297.

110. U.S. v. Hagler, 700 F.3d 1091, 1097 (7th Cir. 2012). U.S. v. Sylla, 790 F.3d 772, 775 (7th Cir. 2015).

111. 18 U.S.C. § 3282(b); *see* 18 U.S.C.A. §§ 2241-48 (sexual abuse offenses).

112. People v. Martinez, 52 A.D.3d 68 (N.Y.S. Ct. App. Div. 2008).

113. State v. Yonage, 321 P.3d 1127 (Utah 2013); State v. Burdick, 395 S.W.3d 120 (Tenn. 2012); People v. Robinson, 47 Cal.4th 1104, 1133, 1140-43 (Cal. 2010) (collecting authorities in support of this proposition); Com v. Dixon, 938 N.E.2d 878 (Mass. 2010). *C.f.* State v. Belt, 179 P.3d 443 (Kan. 2008) (agreeing "in the abstract" that DNA-based John Doe warrants may satisfy particularity requirements, but dismissing three John Doe warrants that did not include unique DNA profiles of their subjects).

114. U.S. v. Marion, 404 U.S. 307 (1971).

115. U.S. v. Lovasco, 431 U.S. 783, 795 (1977).

116. *See, e.g.*, Roberts v. State, 234 So.3d 1251, 1268-69 (Miss. 2017); Com. v. Dame, 45 N.E.3d 69 (Mass. 2016); People v. Cordova, 62 Cal. 4th 104, 118-20 (2015); U.S. v. Hagler, 700 F.3d 1091, 1098-1100 (7th Cir. 2012); State v. McGuire, 786 N.W.2d 227 (Wisc. 2010); Graham v. Com., 319 S.W.3d 331, 341-42 (Ky. 2010); People v. Nelson, 43 Cal. 4th 1242, 1249-57 (2008); State v. Montano, 65 P.3d 61 (Ariz. 2003); Clark v. State, 774 A.2d 1136 (Md. App. 2001).

117. Brady v. Maryland, 373 U.S. 83 (1963).

118. In re Brown, 17 Cal. 4th 873 (1998) (*Brady* violation where prosecution failed to disclose to capital defendant the positive results of a drug test, despite the fact that the crime lab did not inform the prosecution of such results); U.S. ex rel. Smith v. Fairman, 769 F.2d 386 (7th Cir. 1985) (*Brady* violation where prosecution failed to disclose to the defendant information that the defendant's firearm was non-operable, despite the fact that the crime lab did not inform the prosecution of such information).

119. U.S. DEP'T OF JUSTICE, OFF. OF JUSTICE PROGRAMS, NCJ 237975, DNA FOR THE DEFENSE BAR, at 31 (2012).

120. District Attorney's Office for Third Judicial Dist. v. Osborne, 557 U.S. 52 (2009).

121. *Id*. at 62-63.

122. California v. Trombetta, 467 U.S. 479, 489 (1984).

123. Arizona v. Youngblood, 488 U.S. 51, 58 (1988).

124. United States v. Kingsbury, 317 F.Supp.3d 476, 478-79 (D.D.C. 2018) (collecting cases); State v. Ferguson, 20 S.W.3d 485, 496 (Mo. 2000), *cert. denied* 531 U.S. 1019 (2000).

125. 34 U.S.C. § 12592 (b)(3)(C).

126. An electropherogram is a graphic representation of the separation of molecules by electrophoresis or other means of separation.

127. CHIN ET AL., *supra* note 2 at § 10:5.

128. See FEDERAL BUREAU OF INVESTIGATION, QUALITY ASSURANCE STANDARDS FOR FORENSIC TESTING LABORATORIES (2011), https://www.fbi.gov/file-repository/quality-assurance-standards-for-forensic-dna-testing-laboratories.pdf/view (last visited Dec. 13, 2018).

129. Frye v. United States, 293 F. 1013 (D.C. Cir. 1923).

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

131. U.S. CONST. Amend. IV ("In all criminal prosecutions, the accused shall enjoy the right … to be confronted with the witnesses against him.").

132. Crawford v. Washington, 541 U.S. 36, 59 (2004).

133. *Id*. at 51–52.

134. *Id*. at 56.

135. Bullcoming v. New Mexico, 564 U.S. 647 (2011) (blood alcohol concentration (BAC) report); Melendez-Diaz v. Massachusetts, 557 U.S. 305 (2009) (lab's sworn affidavit identifying substance as cocaine).

136. Williams v. Illinois, 567 U.S. 50 (2012).

137. *Id*. at 70-71.

138. *Id*. at 57-58.

139. *Id*. at 84-86.

140. *Id*. at 85.

141. *Id*. at 103 (Thomas, J., concurring in part and concurring in judgment).

142. *Id*. at 104, 108-09.

143. Stuart v. Alabama, 139 S.Ct. 36 (2018) (Gorsuch, J., dissenting) (citation omitted).

144. *See e.g.*, Scales v. State, 712 S.E.2d 555, 561-562 (Ga. Ct. App. 2011) (testimony was relevant to explain "why this fourteen year old case is now being prosecuted and how the investigation came to focus on the Defendant"); People v. Harland, 251 P.3d 515, 517 (Colo. App. 2010), *cert. denied* No. 10SC563, 2011 WL 51758 (Colo. 2011) (testimony was relevant because "it explained how defendant became a suspect after scores of leads had not panned out over several months, an important point because (1) absent the explanation, the jury would be left to speculate as to how defendant became a suspect, and (2) defendant's defense was mistaken identity"); Whatley v. State, 146 So.3d 437 (Ala. App. 2010), *cert. denied* 135 S.Ct. 90 (2014); State v. McMilian, 295 S.W.3d 537 (Mo. App. 2009) (testimony was "necessary to explain the significant passage of time between the offense and McMilian's identification"); People v. Jackson, 903 N.E.2d 338 (Ill. 2009) (testimony was "necessary to explain how defendant came to be identified as the

source of the DNA recovered at the crime scene"); Atteberry v. State, 911 N.E.2d 601, 609 (Ind. App.2009) (testimony was relevant "to show why Atteberry, living in St. Louis, was a suspect in an Indianapolis murder").

145. *See, e.g.,* Scales, 712 S.E.2d at 561; *McMilian*, 295 S.W.3d at 539; *Atteberry*, 911 N.E.2d at 609.

146. *See, e.g.*, State v. Lang, 954 N.E.2d 596, 618 (2011) (affirming admission of DNA test results where random match probability was 1 in 3,461); United States v. Graves, 465 F. Supp. 2d 450, 457-59 (E.D. Pa. 2006) (admitting results DNA test results re: DNA evidence on sneakers where random match probability of 1 in 2,900 to 1 in 3,600, but excluding DNA test results re: DNA evidence on an umbrella where random match probability was 1 in 2); Commonwealth v. O'Laughlin, 843 N.E.2d 617, 633 (Mass. 2006) (affirming admission of DNA test results where the random match probability was 1 in 2); U.S. v. Morrow, 374 F. Supp. 2d 51, 62-66 (D.D.C. 2005); (affirming admission of DNA test results where random match probability ranged between 1 in 1 and 1 in 12); U.S. v. Hicks, 103 F.3d 837, 844-47 (9th Cir. 1996), *cert. den*. 520 U.S. 1193 (1997), *partially overruled on other grounds by* U.S. v. W.R. Grace, 526 F.3d 499 (9th Cir. 2008) (en banc) (affirming admission of expert's testimony that DNA testing could not exclude defendant as a possible contributor to a DNA sample from a vaginal swab).

147. *Morrow*, 374 F. Supp. 2d at 68; *see also* Graves, 465 F. Supp. 2d at 459.

148. Commonwealth v. Mattei, 920 N.E.2d 845, 848 (Mass. 2010) (trial court erred in admitting "expert testimony that DNA tests could not exclude the defendant as a potential source of DNA found at the crime scene, absent testimony regarding statistical findings explaining the import of such a result").