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How Forensic Science Is Transforming Criminal Justice

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in the Forensic Sciences

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Director, National Institute of Justice

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DIRECTOR'S MESSAGE



With advancements in DNA, digital forensics, innovative technologies, and robust analytical methods, forensic science is transforming the criminal justice system. It is helping practitioners identify perpetrators of violent crimes, exonerate the innocent, and apprehend and justly prosecute criminals.

NIJ is the only federal agency supporting programs dedicated to forensic science research, development, and evaluation in conjunction with capacity building and technical assistance. We remain committed to a sustained national effort to develop faster and more discriminatory forensic science methods, while helping laboratories enhance capacity and improve efficiency. These efforts are instrumental in furthering the initiatives of the Attorney General to improve the quality and timeliness of forensic science services and eliminate backlogs in the processing and analysis of forensic evidence.

We chose to focus this issue of the *NIJ Journal* on forensic science topics and policy areas that are highly complex and sometimes not fully understood, including sexual assault investigations and missing persons and unidentified decedents cases. Articles on advanced imaging and 3D printing technologies discuss the challenges of adapting technological advancements in an operational environment. Another article looks to alleviate some of the confusion regarding erroneous convictions, DNA exonerations, and the role of forensic science. Throughout this *Journal* issue, we identify areas in which more scientific knowledge and understanding are needed to inform and advance policies and practices across the country, which is core to NIJ's mission.

Since coming to NIJ, I have gained an appreciation for the important role NIJ's forensic science research and development work plays in the criminal justice system. Research yields benefits beyond advancing knowledge and technology. For example, robust forensic science methods provide critical scientific underpinnings for investigations and prosecutions, as well as powerful crime prevention tools when used to apprehend violent criminals and, in turn, stop them from perpetrating additional crimes. Forensic science allows us to further the Department of Justice's goal to increase public safety.

NIJ has a unique dual mission when it comes to forensic science. We support strengthening the accuracy, reliability, and validity of the forensic sciences. But we also know that as the value of forensic testing has been increasingly recognized, the demand for forensic analysis has grown exponentially. This is especially evident with DNA analysis, as well as forensic drug and toxicology testing resulting from the opioid epidemic and the rise in the use of designer drugs. To help combat these issues, NIJ provides funding directly to state and local laboratories to increase laboratory capacity and reduce the backlogs of evidence, because providing timely information to law enforcement and the courts ultimately bolsters the administration of justice.

I am proud to say that I am committed to a strategy that couples rigorous research and development with capacity enhancement and technical assistance to serve the law enforcement and forensic science communities and further the priorities of the Department of Justice by helping reduce violent crime, supporting prosecutors, and advancing new technologies and strategies that enhance public safety.

A handwritten signature in black ink that reads "David B. Muhlhausen". The signature is written in a cursive style and is followed by a long horizontal line.

David B. Muhlhausen, Ph.D.
Director, National Institute of Justice

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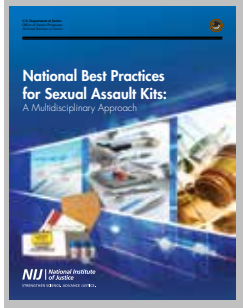
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NIJ BULLETIN



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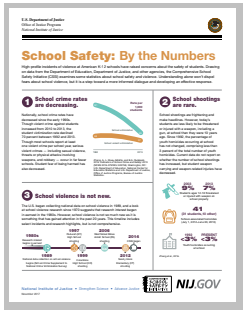


National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach

Behind every sexual assault case is a person whose life has been irrevocably altered. To support victim-centered approaches for responding to sexual assault cases, NIJ recently released a report on best practices for handling sexual assault kits. In the report, NIJ's expert working group puts forward 35 recommendations for better supporting sexual assault victims throughout the criminal justice process.

The report's best practices offer multidisciplinary guidelines that emphasize inclusion and collaboration for all those involved in responding to sexual assault cases, from medical personnel and forensic laboratories to law enforcement and policymakers. Practitioners can apply these approaches to avoid re-traumatization and serve victims more effectively at all stages of the process.

Read "National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach" at NIJ.ojp.gov, keyword: SAFER.

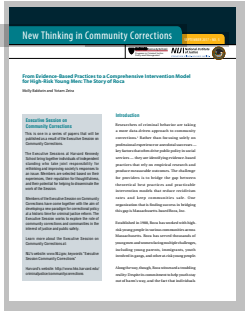


School Safety: By the Numbers

Students who are victimized at school are prone to truancy, poor academic performance, dropping out of school, and violent behaviors. Although schools can be safe havens relative to the communities in which they are located, school safety and security remain pressing issues. The good news is that theft, violent crime, and student homicides in American schools have declined over the past decade.

Drawing on data from the Department of Education, Department of Justice, and other agencies, the Comprehensive School Safety Initiative (CSSI) examines statistics about school safety and violence. A recent NIJ flier offers a quick look at six of these school safety statistics, showing that school crime rates are falling, although traumatic events remain common in schools. Social media remains a relative blind spot in understanding school bullying and harassment.

Read the flier at NIJ.ojp.gov, keyword: by the numbers.



From Evidence-Based Practices to a Comprehensive Intervention Model for High-Risk Young Men: The Story of Roca

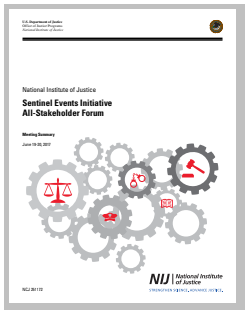
Since 1988, the Massachusetts organization Roca has worked with thousands of high-risk young people, including young parents, immigrants, and youth involved in gangs. In the mid-2000s, Roca embraced an evidence-based, data-driven approach to reducing recidivism. The result, Roca’s High-Risk Young Men Intervention Model, is a program dedicated to serving 17- to 24-year-old men at the highest risk of future incarceration. Relying on rigorous analysis and proven practices, Roca’s model has brought marked improvements to participants. In Massachusetts overall, 76 percent of the 18- to 24-year-olds released from Houses of Corrections are re-arrested within three years. After completing two years of the Roca program, however, just 7 percent of participants are rearrested.

In a recent paper co-sponsored by NIJ and the Harvard Kennedy School, authors Molly Baldwin and Yotam Zeira examine how Roca has bridged the gap between theoretical best practices and practicable intervention models. The paper traces how Roca integrated eight evidence-based practices in community corrections, offering solutions for other community corrections organizations to apply these practices in their own work.

Read “From Evidence-Based Practices to a Comprehensive Intervention Model for High-Risk Young Men: The Story of Roca” at NIJ.ojp.gov, keyword: roca.



News & Events



Sentinel Events Initiative All-Stakeholder Forum

When errors, unethical behavior, or unexpected outcomes occur in criminal justice, the most common response is to assign blame. In June 2017, nearly 100 federal, state, and local criminal justice practitioners, researchers and academics, policymakers, crime survivors, community representatives, and federal partners convened to discuss how to shift that response. Their discussion focused on mechanisms for learning from errors to improve the system rather than simply blaming bad actors. These stakeholders explored the potential benefits of developing the capacity for state- and local-level sentinel event reviews (SERs), along with the barriers to establishing SERs within criminal justice.

Learn more about the meeting’s guiding principles, questions, and conclusions at NIJ.ojp.gov, keyword: sentinel.



The Evolution of SNPs as a Forensic Marker

Single nucleotide polymorphisms (SNPs) are small DNA sequence variations observable across groups and individuals. In November 2017, NIJ’s Forensic Technology Center of Excellence hosted a webinar on SNPs in which Kenneth Kidd discussed their history as forensic markers and highlighted some of the resources that are available to practitioners. Christopher Phillips and Thomas Parsons discussed the design and development of large SNP multiplexes for forensic and missing person identification, and Daniele Podini discussed assays on simulated forensic samples for individual identification and ancestry prediction.

Learn more at <https://forensiccoe.org/event/webinar-the-evolution-of-snps-as-a-forensic-marker-live/>.



Winners of the Crime Forecasting Challenge

How can the location of crime be predicted in advance? The Real-Time Crime Forecasting Challenge sought to harness advances in data science to address this challenge. It encouraged data scientists across all scientific disciplines to foster innovation in forecasting methods. The goal was to develop algorithms that advance place-based crime forecasting through the use of data from one police jurisdiction. Specifically, the Challenge tested how effectively and efficiently contestants' crime forecasting algorithms could forecast police calls for service in four crime categories in Portland, Oregon, for five forecast periods.

In August 2017, winners were selected from submissions by five students, 42 small teams/businesses, and 15 large businesses. Learn more and read the winning submissions at NIJ.ojp.gov, keyword: forecasting.



Multimedia



Why Is There an Evidence Backlog?

Forensic evidence is collected from crime scenes, victims, and suspects in criminal cases and then submitted to a laboratory. Processing this evidence is time-consuming because it must first be screened to determine whether any biological material is present and, if so, what kind of biological material it is. Only then can DNA testing begin. The demand on crime laboratories is often higher than their capacity, causing a backlog of unprocessed, untested evidence.

Several federal grant programs have made a significant contribution to clearing backlogs of forensic DNA evidence in crime laboratories. Between 2004 and 2011, NIJ awarded approximately \$542 million to state and local DNA laboratories. Federal funding helped these laboratories increase capacity almost fourfold between 2005 and 2010. At the same time, most jurisdictions remain hard-pressed to keep up with the demand. To illustrate the problem of evidence backlogs, NIJ released a short video explaining where the backlog comes from and what NIJ is doing to address it.

Watch "Why Is There an Evidence Backlog?" at NIJ.ojp.gov, keyword: why backlog.



Impact of Research and Development on Lab Efficiency and Operations

How does research affect evidence processing and analysis within crime laboratories? With an understanding of the barriers to meeting caseload demands faced by forensic scientists, NIJ supports research and development that improve the efficiency and effectiveness of the nation's crime laboratories. In a new video, NIJ highlights the connection between forensic science research, improved processes, and better justice outcomes.

Watch "Impact of Research and Development on Lab Efficiency and Operations" at NIJ.ojp.gov, keyword: impact of R&D.



Recent Research Findings



Assessing and Responding to the Recent Homicide Rise in the United States

U.S. homicide rates rose substantially in 2015 and 2016. In big cities, homicides increased by 15.2 percent between 2014 and 2015, and by 10.8 percent between 2015 and 2016. These increases are much larger than has been typical of yearly homicide fluctuations over the past several decades, so they merit close attention.

A new publication from NIJ considers two explanations for the homicide rise: expansion in illicit drug markets brought about by the heroin and synthetic opioid epidemic, and “Ferguson effects” resulting in de-policing and compromised police legitimacy. After analyzing these two phenomena, the paper concludes with recommendations for future research.

Read “Assessing and Responding to the Recent Homicide Rise in the United States” at NIJ.ojp.gov, keyword: homicide.



Pathways Between Child Maltreatment and Adult Criminal Involvement

Child abuse and neglect have been shown to increase the risk of later forms of antisocial behavior, including violence perpetration and crime in adulthood. However, the processes through which child abuse leads to subsequent antisocial and criminal behavior are not well understood.

A recent NIJ-funded study suggests that interventions aimed at reducing negative consequences of child abuse on adult criminal behavior should be tailored to the developmental timing of the antisocial behavior. Tailoring intervention efforts to address different factors in the pathways linking child abuse and adult crime may more effectively promote desistance from antisocial behavior associated with childhood abuse.

Learn more about the research and read the report at NIJ.ojp.gov, keyword: child.



Computers Learn to Detect Financial Abuse of the Elderly

A recent NIJ-funded study found that machine learning may provide a new avenue for creating tools to identify financial exploitation among elderly adults. Carmel Dyer, Jason Burnett, and their team used a Texas adult protective services, administrative, statewide data set with 8,800 confirmed cases of elder abuse. The data were randomly split 80/20. The larger data set was used to train the computer to detect patterns of financial exploitation; the smaller data set was used to test the computer models on accuracy in classifying the financial exploitation cases.

The study demonstrated an innovative way to leverage administrative data to understand patterns of financial exploitation. The computer was able to learn how to distinguish financial exploitation from other types of elder abuse and further learn patterns of pure financial exploitation versus hybrid financial exploitation.

Learn more about the study and read the researchers' final report at NIJ.ojp.gov, keyword: 251227.



New NIJ.ojp.gov Pages



Linking Suspects to Crime Scenes with Particle Populations

David and Paul Stoney, two brothers who operate Stoney Forensic in Chantilly, Virginia, have long believed that the innumerable very small particles (VSP) in the environment can be used to solve crimes. Their earlier research established the viability of using such particles for two important forensic purposes: matching an object found at a crime scene to a suspect's vehicle or residence, and tracing the recent history of where an object has been. In a new NIJ-funded study, the researchers sought to determine the evidential value of VSP profiles found on handguns, cell phones, drug packaging, and ski masks. The samples tested were actual evidence held by the San Diego Sheriff's Office. Overall, 82 percent of the VSP specimens recovered showed "sufficient variety and complexity in their VSP profiles to allow meaningful classification."

Read an article about the study at [NIJ.ojp.gov](https://www.nij.ojp.gov), keyword: linking suspects.



Fast and Versatile Forensic Analysis of Ink and Paper with an Easily Operated Laser

Information from the forensic examination of inks and paper can be critical to investigations involving financial crimes, counterfeiting, terrorism, and anonymous letters used for threatening correspondences, ransom notes, and kidnappings. Laser-induced breakdown spectroscopy (LIBS) instruments, which can detect practically the entire periodic table of elements very quickly and without the complexity of other systems, are an economic choice for forensic analysis of this ink-and-paper evidence.

In an NIJ-supported project, researchers at Florida International University compared LIBS systems to a more complex and costly mass spectrometry system. More than 97 percent of writing inks and up to 100 percent of printing inks were correctly discriminated by the LIBS system. The researchers concluded that LIBS, while less mature, offers improved speed, versatility, ease of operation, affordability, and portability.

Read an article about the project at [NIJ.ojp.gov](https://www.nij.ojp.gov), keyword: fast and versatile.



Establishing Scientific Criteria for 3D Analysis of Cartridges

Recent NIJ-funded research has established best practices for using the TopMatch system, an advanced 3D imaging and analysis system for firearm forensics. The research demonstrated excellent repeatability and precision in the scans produced by the technology for analyzing cartridges. Ryan Lillien, the scientist and developer of TopMatch whose work was supported by NIJ, says that the work "sets a solid foundation on which our scanning methodology and comparison algorithms can build."

Read an article about the system at [NIJ.ojp.gov](https://www.nij.ojp.gov), keyword: 3D.



Sharing Data to Improve Science



Data Resources Program

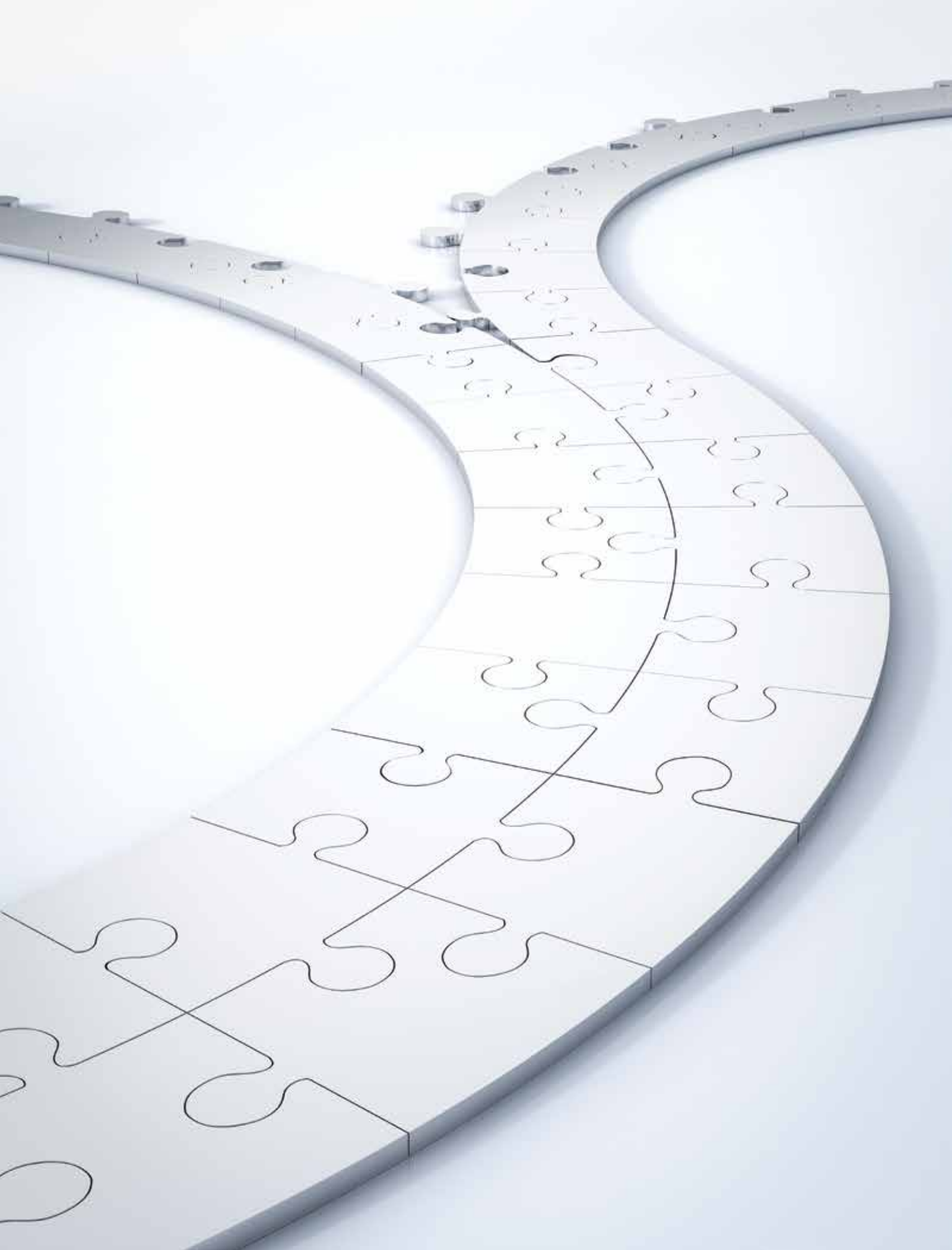
Secondary data analysis allows researchers to build on existing findings, replicate results, and conduct new analyses. Through NIJ's Data Resources Program, data collected as part of NIJ research are archived in the National Archive of Criminal Justice Data and made available to support new research aimed at reproducing original findings, replicating results, and testing new hypotheses.

- Learn about NIJ's Data Resources Program at nij.ojp.gov, keyword: DRP.

Recent data sets updated or added to the National Archive include the following:

- An Examination of Child Support, Debt and Prisoner Reentry Using the SVORI Adult Male Dataset, 2004-2007
- Assessing the Influence of Home Visit Themes and Temporal Ordering On High-Risk Parolee Outcomes, Georgia, 2011-2015
- Elder Abuse in the 2010 National Intimate Partner and Sexual Violence Survey (NISVS)
- Evaluation of a Novel Fluorescent Dye to Detect Anogenital Injury, Virginia, 2015-2016
- Examining the Effects of the TASER on Cognitive Functioning, Arizona, 2012-2013
- Identification of Risk and Preventive Factors for Elder Financial Exploitation, Los Angeles, 2014-2015
- Police Practitioner-Researcher Partnerships: Survey of Law Enforcement Executives, United States, 2010
- Research on the Impact of Technology on Policing Strategy, 2012-2014
- Secondary Analysis of Survey of Youth in Residential Placement (SYRP), 2003
- The Long-Term Effects of Civil Legal Services on Battered Women, Iowa, 2012-2015

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WRONGFUL CONVICTIONS AND DNA EXONERATIONS: UNDERSTANDING THE ROLE OF FORENSIC SCIENCE

BY GERALD LAPORTE

A review of erroneous convictions that involved forensic science can help identify critical lessons for forensic scientists as they perform testing, interpret results, render conclusions, and testify in court.

One of the greatest tragedies in the criminal justice system is the conviction of a person for a crime he or she did not commit. Erroneous convictions can have immeasurable consequences for exonerees, original crime victims, and families (see sidebar, “NIJ Listening Sessions with Victims and Exonerees of Wrongful Conviction”).¹ Additionally, they may also have long-lasting negative effects on the witnesses, investigators, lawyers, judges, and other criminal justice professionals involved in erroneous convictions. It is therefore incumbent on us to understand the root causes of these tragic events to help ensure that injustice is not repeated.

Wrongful conviction cases have been associated with various causes, which will be discussed throughout this article; however, we specifically examine cases that included forensic science as a contributing factor. Our analysis reviews publicly available data on erroneous convictions and then presents a summary of the cases that have cited forensic science as a potential factor. The goal is to identify what we can learn from these cases to help mitigate the potential

for erroneous convictions when forensic scientists perform testing, interpret results, render conclusions, and testify to their findings. During the analysis phase of this study, some inconsistencies were identified with respect to information that is generally available via websites and publicly accessible databases. Also of concern, there is a lack of understanding and reliance on formal research studies that are generally based on a robust experimental design.

There will undoubtedly be debate as to the ultimate impact of forensic science in many of the exonérations reviewed. The extent to which forensic science is a contributing factor in each case will often include a certain degree of subjective interpretation because the majority of erroneous convictions involve complex investigations, multiple contributing factors, complicated juror decisions, and mistakes from policies and practices that have since changed. Moreover, we do not have all of the details or full transcripts from the evidence and testimony presented at trial, which may further inhibit our understanding and bias our opinions.

The work we do as forensic scientists and the conclusions we reach have lasting effects on people’s lives, so we must pursue every effort to understand and identify our weaknesses.

It is most important for forensic scientists to understand that the work we do and the conclusions we reach — either in forensic reports or testimony — have lasting effects on people’s lives, so we must pursue every effort to understand and identify our weaknesses.

Inconsistencies in Publicly Available Data

According to the Innocence Project, a national litigation and public policy organization dedicated to exonerating wrongfully convicted individuals, 342 people have been exonerated as a result of DNA analysis as of July 31, 2016.² The Innocence Project lists six “contributing causes” for wrongful convictions:

- Eyewitness misidentification
- False confessions or admissions
- Government misconduct
- Inadequate defense
- Informants (e.g., jailhouse snitches)
- Unvalidated or improper forensic science

However, Jon Gould, who has written extensively about erroneous convictions, and his colleagues caution that “without a comparison or control group of cases, researchers risk labeling these factors as ‘causes’ of erroneous convictions when they may be merely correlates.”³ They designed a unique experimental strategy to study factors leading to rightful acquittals or dismissal of charges against an innocent defendant — near misses — that were

not present in cases that led to the conviction of an innocent person. After identifying a set of erroneous convictions and near misses and analyzing the cases using bivariate and logistic regression techniques, Gould and his colleagues identified 10 “factors” (not causes) that led to a wrongful conviction of an innocent defendant instead of a dismissal or acquittal:

- Younger defendant
- Criminal history
- Weak prosecution case
- Prosecution withheld evidence
- Lying by a non-eyewitness
- Unintentional witness misidentification
- Misinterpreting forensic evidence at trial
- Weak defense
- Defendant offered a family witness
- States with a “punitive” culture

Rebecca Goldin, a professor of mathematical sciences, has also written about the challenge of conveying the differences between causation and correlation. As Goldin states:⁴

Journalists are constantly being reminded that correlation doesn’t imply causation; yet, conflating the two remains one of the most common errors in news reporting on scientific and health-related studies If one action causes another, then they are most certainly correlated. But just because two things occur together does not mean that one caused the other, even if it seems to make sense.

The Innocence Project’s website includes a referenced link to “unvalidated or improper forensic science” for 157 cases (46 percent) of the 342 cases. If we cross-reference the same 157 cases on the National Registry of Exonerations’ (NRE’s) website — a project that collects information about all known exonerations from 1989 to the present⁵ — we find some inconsistencies in how the Innocence Project and NRE classify forensic science as a factor, making it challenging to reconcile the data. NRE is managed

by the Newkirk Center for Science and Society at the University of California, Irvine; the University of Michigan Law School; and the Michigan State University College of Law. It identifies 133 DNA exoneration cases (39 percent), from the same pool of cases identified by the Innocence Project, in which forensic science is a contributing factor.

Exhibit 1 lists information on the 24 discrepant cases. A review of each of these cases, including case narratives from both the Innocence Project and NRE and internet articles when applicable, found that in these cases, the Innocence Project’s website did not include a clear description of the improper forensic science, there was ambiguity in the narrative, and

the evidence described was actually exculpatory. As stated previously, some erroneous convictions involved subjective assessments when it comes to contributing factors (see sidebar, “The Case of Steven Avery”).

Further, the NRE website lists a total of 1,944 exonerations since 1989 (this includes both non-DNA and DNA exonerations), and improper forensic science is cited in 24 percent of *all* exonerations, not just DNA exonerations such as those reported by the Innocence Project. Researchers John Collins and Jay Jarvis also discuss the discrepancy in the percentages of exonerations citing forensic science as a contributing factor.⁶ Therefore, for the purpose of this article, we use the 133 cases listed by NRE — not the 157

Exhibit 1. Discrepant Cases

	Exoneree	State	Innocence Project Forensic Narrative	Contributing Factor(s) Listed on National Registry of Exonerations
1	Avery, Steven	WI	Microscopic hair examination	Mistaken witness identification
2	Burnette, Victor	VA	Microscopic hair examination	Mistaken witness identification
3	Cotton, Ronald	NC	No description of a forensic error	Mistaken witness identification
4	Cunningham, Calvin	VA	Hair: Exculpatory, similar but not consistent	Mistaken witness identification
5	Cruz, Rolando	IL	Co-defendant (not guilty); boot print	False confession; perjury or false accusation; official misconduct
6	Gray, David	IL	No secretor testing performed	Mistaken witness identification; perjury or false accusation; official misconduct
7	Halsey, Byron	NJ	Uncertain	False confession; perjury or false accusation
8	Hernandez, Alejandro	IL	Co-defendant (not guilty); boot print	False confession; perjury or false accusation; official misconduct
9	Jones, Ronald	IL	ABO blood typing	Mistaken witness identification; false confession; official misconduct
10	McClendon, Robert	OH	No description of a forensic error	Mistaken witness identification
11	McSherry, Leonard	CA	No description of a forensic error	Mistaken witness identification
12	Nesmith, Willie	PA	No description of a forensic error	Mistaken witness identification

continued on the next page

Exhibit 1. Discrepant Cases (continued)				
	Exoneree	State	Innocence Project Forensic Narrative	Contributing Factor(s) Listed on National Registry of Exonerations
13	Ochoa, James	CA	No description of a forensic error; fingerprint and DNA exculpatory	Mistaken witness identification; official misconduct
14	Powell, Anthony	MA	No description of a forensic error; DNA not admissible at the time	Mistaken witness identification; official misconduct
15	Rivera, Juan	IL	No description of a forensic error	Mistaken witness identification; false confession; perjury or false accusation; official misconduct
16	Snyder, Walter	VA	No description of a forensic error	Mistaken witness identification; false confession; perjury or false accusation; official misconduct
17	Towler, Raymond	OH	No description of a forensic error; hair lacked sufficiency	Mistaken witness identification
18	Turner, Keith	TX	No description of a forensic error	Mistaken witness identification
19	Waller, James	TX	No description of a forensic error; hair was not the same	Mistaken witness identification
20	Waller, Patrick	TX	No description of a forensic error; ABO could not exclude	Mistaken witness identification
21	Warney, Douglas	NY	No description of a forensic error; ABO was exculpatory	False confession; official misconduct
22	Whitley, Drew	PA	No description of a forensic error; hair was similar, but analyst could not be certain	Mistaken witness identification; perjury or false accusation
23	Williams, Willie	GA	No description of a forensic error	Mistaken witness identification
24	Woods, Anthony	MO	No description of a forensic error	Mistaken witness identification

cases cited by the Innocence Project — for further analysis.

NRE lists six categories of “contributing factors” (not causes) that are similar to those on the Innocence Project’s website:

- Mistaken witness identification or eyewitness misidentification
- Perjury or false accusation

- False confession
- Official misconduct
- Inadequate legal defense
- False or misleading forensic evidence

Although neither the Innocence Project nor NRE use the 10 factors identified by Gould and his colleagues, NRE’s categorical descriptions are more aligned with the academic literature and were therefore used for this article.

Forensic Science

Unlike any other single scientific discovery, advances in DNA technology have improved how we investigate cases and interpret forensic evidence (see sidebar, “NIJ’s Postconviction DNA Testing Program”). Because DNA can provide factually irrefutable evidence in some cases, the idea that innocent people can be found guilty has gained more awareness and acceptance over the past two decades. As a result, we have come to learn more about erroneous convictions.

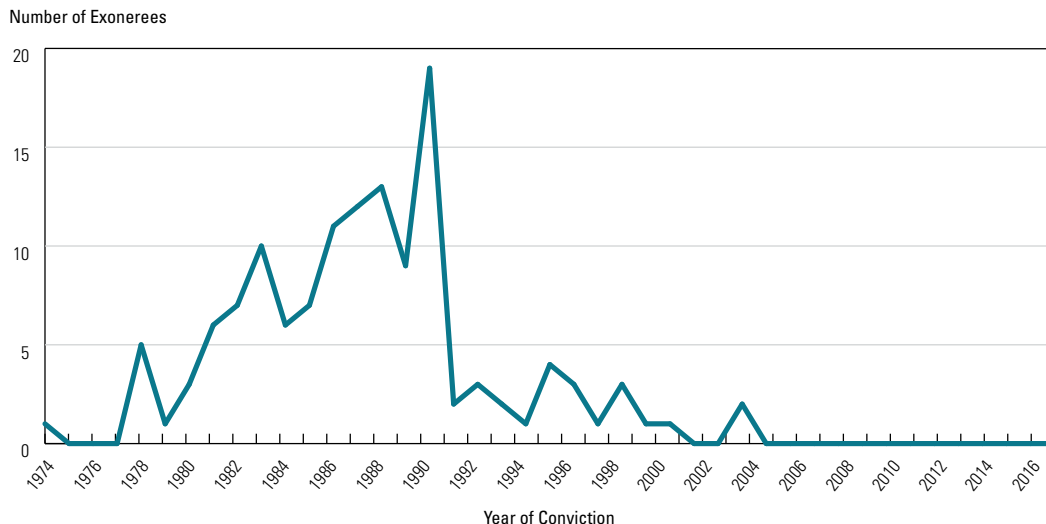
Nonetheless, the use of forensic science has also been linked with wrongful convictions in past cases and characterized in the media and legal reviews as “faulty,” “misleading,” and “junk science.” Forensic science — when incorrectly perceived as a single discipline — causes observers to conflate matters and acquire their own misperceptions about all forensic science disciplines. Moreover, there can be a variety of methods within a single forensic discipline — and it is often a method, not the entire discipline, that may have been improperly applied or interpreted. Even more pervasive, references to wrongful convictions in the popular media do not cite scholarly articles and often rely on other media articles and unverified sources.

To demonstrate the diversity of forensic science disciplines, the National Institute of Standards and Technology coordinates the development of standards through the Organization of Scientific Area Committees (OSAC) for Forensic Science. The OSAC has identified 23 forensic science subcommittees,⁷ which include a variety of disciplines and subdisciplines, such as bloodstain pattern analysis, firearms and tool marks, forensic toxicology, forensic odontology, trace evidence, and mitochondrial DNA analysis. As we discuss later in this article, the majority of wrongful convictions have been associated with serology (e.g., ABO blood typing and secretor status) and microscopic hair analysis, a subdiscipline of trace evidence. ABO blood typing has a strong scientific foundation and is based on well-founded population statistics, so the root cause of many of these exonerations is likely not a weak foundation in the science but possibly in how the results are interpreted and conveyed — if, in fact, the forensic science analysis substantively contributed to the erroneous conviction.

A Closer Look at the Cases

Exhibit 2 shows the number of exonerations from 1974 through 2003 in which NRE cites forensic

Exhibit 2. Number of Exonerees by Year of Conviction



Note: Data are based on 133 cases of wrongful conviction listed by the National Registry of Exonerations, 1974-2016.

science as a contributing factor. Based on the year of conviction, 83 percent (110 cases) occurred before 1991, but only two exonerations occurred after 2000, both in 2003. In the first case, according to NRE's website, a DNA analyst identified seminal fluid in two different areas on the victim's underwear. The results from one of the samples excluded Ronjon Cameron; the results from the second sample neither included nor excluded him. More sophisticated DNA testing in 2012 excluded Cameron as the contributor. An examiner reviewed the original case and concluded that Cameron should have been excluded at the time of trial.⁸ NRE lists inadequate legal defense, perjury, and false accusations as other contributing factors in the case. The victim also stated that Cameron, whom she knew, was the perpetrator. In the second case, DNA samples from two suspects, Dewayne Jackson and his cousin Dupree Grissom, were inadvertently swapped. Jackson was wrongfully convicted, but in 2010, Grissom was convicted of a separate crime and then linked to the original crime.⁹

In the 133 DNA exoneration cases, 55 percent of the exonerees are African American, 38 percent are Caucasian, and 7 percent are Hispanic.¹⁰ With respect to the original crime victims, 69 percent are Caucasian, 13 percent are African American, 6 percent are Hispanic, and 12 percent are unknown. Also, approximately 15 percent of the original crime

victims were under the age of 18 at the time of the crime, and a significant number of victims could be perceived as "vulnerable," such as young female adults (e.g., under age 25) and elderly females (e.g., over age 60). A detailed analysis of exoneree demographics and their relationship to crime type and contributing factors or whether victimology influences investigations, prosecutions, and jury decisions in erroneous convictions was not the subject of this report, but it might prove an interesting area for future research.

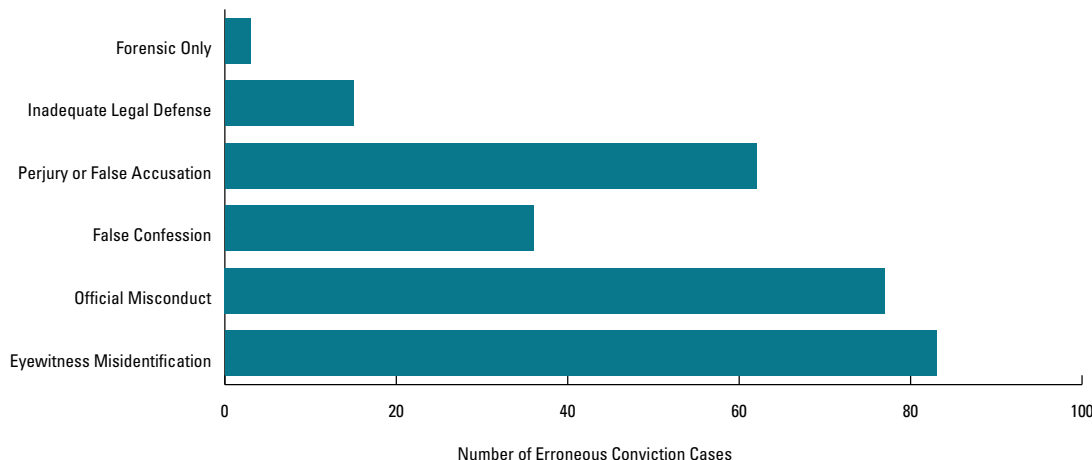
Erroneous convictions, like most catastrophic mistakes in the criminal justice system, are rarely caused by a single identifiable act or weakness. Instead, multiple failures in the process can lead to a negative outcome. Of the 133 DNA exonerations, 98 percent also involved two to five additional contributing factors (see exhibit 3). Only 2 percent (three cases) cited forensic science as the sole contributing factor. The largest number, 36 percent (48 cases), included forensic science and two additional factors.

Exhibit 4 shows the relationship when forensic science is cited as a contributing factor along with other contributing factors — inadequate legal defense, perjury or false accusation, false confession, official misconduct, and mistaken witness identification. The most significant number of wrongful convictions in

Exhibit 3. Contributing Factors to Wrongful Convictions

Forensic Science (FS) + Number of Additional Contributing Factors	Number of Cases (%)
FS	3 (2%)
FS + 1 additional contributing factor	39 (29%)
FS + 2 additional contributing factors	48 (36%)
FS + 3 additional contributing factors	36 (27%)
FS + 4 additional contributing factors	6 (5%)
FS + 5 additional contributing factors	1 (1%)
Total	133 (100%)

Exhibit 4. The Relationship Between Forensic Science and Other Contributing Factors in Erroneous Convictions



Note: Data are based on 133 cases of wrongful conviction listed by the National Registry of Exonerations, 1974-2016.

which forensic science is considered a contributing factor is attributable to eyewitness misidentification and official misconduct.

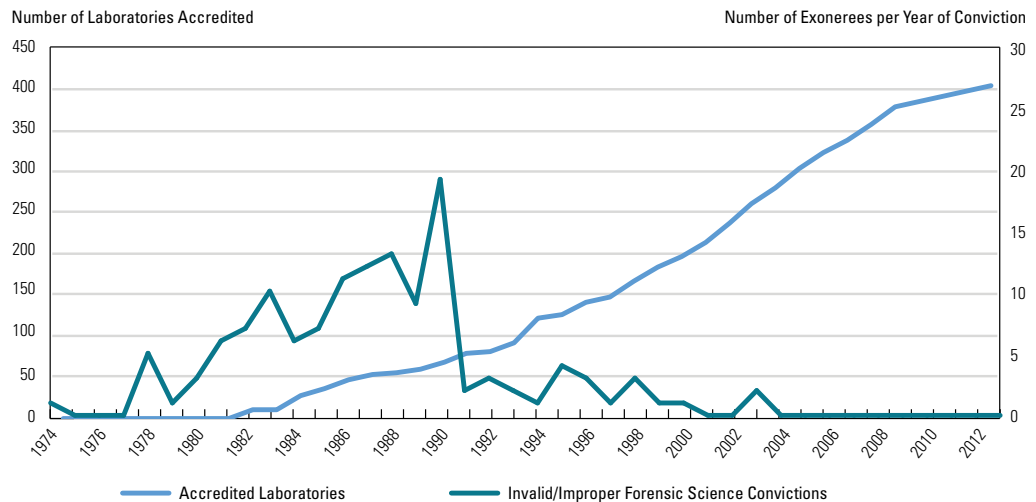
Official Misconduct Cases

The most egregious cases involve malfeasance or official misconduct. There were at least 16 cases from 1980 to 1991 involving forensic charlatans, all of whom were later terminated. Sadly, the testing results in some of those cases would have exculpated the exoneree.

One effective strategy to reduce misconduct is through a rigorous laboratory accreditation program that includes numerous checks and balances. Collins and Jarvis¹¹ note that only one case out of the 200 they reviewed involved forensic malpractice in an accredited forensic laboratory (in 1988) and state that “[w]hile accreditation is not a promise of perfection, it has enforced professional accountability and transparency that has benefited all stakeholders of forensic science for over 25 years.” According to the Bureau of Justice Statistics, as of December 31, 2014, 88 percent of the nation’s 409 publicly funded forensic laboratories were accredited by a professional forensic science organization, compared with 82

percent in 2009 and 70 percent in 2002.¹² There has been a significant rise in the number of laboratories accredited over the past two decades, which may help to answer why there has not been a significant number of erroneous convictions related to forensic science since the mid-1990s. Exhibit 5 shows the increase in the number of accredited laboratories compared to the number of exonerees per year of conviction.

NRE identified official misconduct at various levels — not just forensic science malpractice — in 77 of the 133 cases. As a root cause, malfeasance can have a pervasive effect on the entire system and jeopardize other mitigating factors that might normally help identify potential errors during the investigation and prosecution stages. The impact of misconduct can be overwhelming to the system. Some modern examples of malfeasance include Annie Dookhan, a forensic chemist at a Massachusetts crime lab who was prosecuted and convicted for falsifying drug test results,¹³ and Sonja Farak, who pleaded guilty to stealing drugs and tampering with evidence, also in a Massachusetts crime lab.¹⁴ Some labs have closed because of a lack of quality control — the Detroit crime lab in 2008, the Nassau County (NY) crime lab in 2011, and the St. Paul (MN) police crime

Exhibit 5. Number of Laboratories Accredited Per Year vs. Number of Exonerations (Year of Conviction)

Note: Data are based on 133 cases of wrongful conviction listed by the National Registry of Exonerations, 1974-2016.

lab in 2012. Although many of these scandals are associated with bad forensic science, the root cause of the failures is the lack of a suitable quality control program or “bad forensic scientists.”

Forensic Methods Associated with Erroneous Convictions

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. Very few (less than 1 percent) of the 133 exonerations involved the traditional forensic science disciplines that are often referred to as “impression and pattern evidence” — latent prints, firearms, bloodstain pattern analysis, footwear and tire tread analysis, and handwriting (see exhibit 6).¹⁵

What does appear to be noteworthy based on the data is that serology, microscopic hair analysis, and bite mark examination involve methods that are used to directly link a suspect to the victim by identifying the person. This is quite different from many other forensic disciplines where there

is an indirect link, such as correlating a footwear impression at a crime scene to a shoe, a bullet to a gun, or even a fingerprint to an object (fingerprints are rarely recovered from the skin of a victim). Perhaps investigators, prosecutors, and jurors perceive forensic evidence that suggests a strong association between the suspect and the victim differently than physical evidence that may not be viewed as a direct association to the victim.

Take, for example, a case in which a rape victim identifies a suspect at the outset, but during the course of the investigation, the suspect’s blood type is determined to match foreign blood on the victim. The direct link between the suspect and victim possibly creates a stronger perceived association. Now consider the same scenario, but instead of matching blood, a shoe impression is found at the scene. When a suspect’s shoe is obtained, there is a need to show links between the suspect and the shoe and between the impression from the crime scene and the shoe. There is also a need to show that the suspect wore the shoe when the crime was committed. This type of evidence may be perceived differently and could potentially result in a scenario that causes investigators and prosecutors to seek more evidence.

Exhibit 6. Forensic Methods Most Frequently Associated with Wrongful Convictions

Forensic Discipline	No. of Cases	Percent of Forensic Cases (N = 133)	Percent of All DNA Exonerations (N = 342)	Range of Years
Forensic biology (serology)	76	57	22	1974-1997
Microscopic hair examination	61	46	18	1978-1998
Bite mark	10	8	3	1985-1998
DNA	7	5	2	1990-2003
Shoe impressions	2	1.5	<1	1982
Fingerprint	1	<1	<1	1997
Fiber	1	<1	<1	1985
Jean pattern	1	<1	<1	1989
Dog scent	1	<1	<1	1978-1981
Voice	1	<1	<1	1985

Jurors might also assign less evidential value to the footwear impression than the blood typing results. More research is needed to assess the perceived probative value of different types of forensic evidence and how they may influence investigations, litigation decisions, and factfinders.

Forensic serology cases

From 1974 to 1997, 76 exoneration cases involved forensic serology. Of course, the evolution of DNA typing superseded blood typing and secretor status, which likely explains why wrongful conviction cases involving forensic serology took place prior to the mid-1990s.

Forty-two (55 percent) of these exonerees were African American, 28 (37 percent) Caucasian, and six (8 percent) Latino. More than half of the cases (43) were associated with some form of official misconduct, and 12 directly involved forensic misconduct. With respect to other contributing factors, 51 also included mistaken witness identifications, 23 involved false confessions, and seven were associated with perjury or false accusations.

A review of these cases finds some subjectivity and ambiguity in how much the forensic serology testimony factored into the wrongful conviction. There does appear to be a number of cases in which mixtures of body fluids from the victim and suspect may have caused misinterpretation of the results. However, without conducting a review of the actual laboratory data and the testimony, it is difficult to assess the impact of the forensic findings. What is clear in many cases is that ABO blood typing and secretor status were used to either include or exclude — but rarely to identify — the exoneree.

Microscopic hair examination

From 1978 to 1998, 61 of the cases involved microscopic hair examination. As with forensic serology methods, DNA analysis (both nuclear and mitochondrial) has become more commonplace when hair is submitted as evidence.

In these cases, 33 (54 percent) of the exonerees were African American, 24 (39 percent) Caucasian, and four (4 percent) Latino. Thirty-six of these cases

NIJ's Postconviction DNA Testing Program

NIJ has contributed considerably to advances in DNA technology and forensic DNA analysis; as a result, our nation's forensic laboratories have adopted new methods and technologies over the past two decades. NIJ also administers the Postconviction Testing of DNA Evidence to Exonerate the Innocent grant program to assist in defraying the costs associated with postconviction case review, evidence location, and DNA testing in violent felony cases where the results of such testing might show actual innocence. Since the program's inception in 2008, NIJ has supported more than 50,000 case reviews that have resulted in 28 exonerations. Learn more at NIJ.ojp.gov, keyword: postconviction.

also involved official misconduct, and seven involved forensic misconduct by two examiners, who were later terminated. Of the 61 cases, 59 also involved eyewitness misidentification, and 17 involved false confessions.

Further, there was some ambiguity in the interpretation of the evidential value of the hair examination. For example, as discussed by Collins and Jarvis, a criminalist testified in one case “that two Caucasian hairs on Clyde’s shirt were microscopically similar (but not conclusively identical) to hair from the victim’s head.” Without understanding the context of the entire testimony and the criminalist’s explanation of “similar (but not conclusively identical)” — as well as the impact of the other factors in this case (e.g., mistaken eyewitness identification) — it is virtually impossible to ascertain with certainty how the microscopic hair examination affected jurors’ decisions. Also, it is important to note that 11 of the exonerees in this group were part of four different cases — not 11 different cases.

Bite mark examinations

From 1985 to 1998, 10 cases involved bite mark examinations; seven of these cases involved official misconduct. Thirty percent (three) of the cases also included mistaken eyewitness identification, which is significantly less than the percentage of cases involving forensic serology and microscopic hair examination. In half of these cases, analyses

performed by defense experts actually exculpated the exonerees; however, the data set is too small to reach any significant conclusions.

Over the years, the American Board of Forensic Odontology (ABFO) has changed its guidance for associating bite mark impressions. In a December 2000 document,¹⁶ 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 eyewitness. 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.”¹⁷

Moving Forward

Unpredictable juror decision-making, the unknown impact of other contributing factors, subjective assessments of information, and lack of complete information result in some uncertainty in how much forensic science has contributed to wrongful convictions. However, there are some critical lessons that forensic scientists can take away from these findings.

First, forensic misconduct is fervently unacceptable; it has a pervasive and infectious effect on the entire criminal justice system. All forensic laboratories and forensic scientists are obliged to make every effort to prevent forensic misconduct. Accreditation, implementation and enforcement of a code of ethics, and appropriate training should mitigate forensic misconduct.

Second, forensic scientists must avoid ambiguous terminology in their reports and testimony because they will mislead investigators, litigators, and factfinders. Forensic science professionals strive to convey their findings accurately and reliably. But terminology such as “consistent with,” “similar to,” and “cannot be differentiated” — qualitative terms that forensic scientists often use to avoid making conclusive statements that two or more items are not from the same source — may be interpreted differently by courts and juries when used in a certain context and not fully explained. These ambiguous phrases can have repercussions beyond what they were originally intended to do, which is for the forensic scientist to communicate uncertainty. Therefore, all forensic disciplines need to clearly define the language they will use and be cognizant of potential misinterpretation by nonscientists.

Third, and along related lines, forensic scientists must convey impartial and objective conclusions based on accurate and reliable techniques. It is also

just as important to clearly articulate limitations and uncertainty so that all users understand the confines of the forensic findings. In reviewing the erroneous convictions that involved forensic serology, there appears to be an underlying issue with mixture interpretation and statistical assessments. Forensic scientists need to demonstrate core competency in the use of and interpretation of statistics. Having an advanced level of statistical training through undergraduate and graduate forensic science programs is essential.

Fourth, errors are often inevitable; when they do occur, it is critical to focus on the underlying problems that contributed to the event — and then to learn from the error. This is an especially challenging issue because the general tendency is to blame an individual.

The final recommendation is best stated in a quote from Dr. Paul Camille Hippolyte Brouardel, a French pathologist: “If the law has made you a witness, remain a man of science. You have no victim to avenge, no guilty or innocent person to convict or save — you must bear testimony within the limits of science.”¹⁸

About the Author

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For More Information

Learn more about NIJ’s work in postconviction testing and wrongful conviction at NIJ.ojp.gov, keyword: postconviction.

The Case of Steven Avery

One case that involved ambiguity was the exoneration of Steven Avery. The Innocence Project's description, which conflicts with the one on the National Registry of Exonerations' website, says that "[a] state forensic examiner testified that a hair recovered from a shirt of Avery's was consistent with Beerntsten's hair [victim]." According to a transcript of the cross-examination of the forensic examiner who conducted the microscopic hair analysis, the examiner located three head hairs on a shirt seized from Avery and concluded that two of the head hairs were inconsistent with the victim's hair.¹ The examiner concluded that the third questioned hair found on the shirt was "consistent" with the victim's hair; however, the examiner then explained that a microscopic hair comparison is not a method that can be used to identify the actual source of a questioned hair.

Here are portions of the cross-examination:

Q: Ms. Culhane, is it possible to prove identification by hair analysis?

A: No.

Q: Is the hair of many people consistent with each other?

A: Yes.

Q: Is it unusual for hair from different people to be consistent with each other?

A: No, it's not.

Q: For example, is it unusual for the hair of white Caucasians to be consistent with each other?

A: No.

Q: If, for example, you took hair from 10 different people, would it be unusual to get consistencies between the hair[s] from those people?

A: No.

Q: It would be usual, wouldn't it?

A: Yes, it would be.

Q: Other than the standards that you have spoken of, did you have any other standards?

A: I did have a pubic hair.

Q: But, of head hair, did you have any standards other than the ones you testified about?

A: No, sir.

Q: You had no standards that were purportedly from hospital or ambulance personnel?

A: No, sir.

Q: Do you have any standard purportedly from the husband of the victim?

A: No, sir.

Q: Any standard purportedly from a Diane Messman or John Gould?

A: No.

Q: Any standard from any of Mr. Avery's children?

A: No, sir.

Q: The hair that you found from the white sheet that was inconsistent with the victim's hair, did you analyze it to determine if it was consistent with Mr. Avery's?

A: No.

Q: The hair that was found on the brown T-shirt, did it have any distinguishing characteristics?

A: By distinguishing, do you mean unusual characteristics?

Q: Yes.

A: No.

Q: Isn't that what makes it possible for you to find a hair inconsistent with another, that it has some distinguishing characteristic?

A: Well, by distinguishing, if you mean characteristics specific to that hair, yes, it does. It has nothing out of the ordinary or unusual that would make it rare or anything like that.

Q: What is it about the hair that makes it possible to distinguish it from other hair?

A: The structural features. By that, I mean the presence of a medulla, which is the center portion of the hair, the color, the diameter.

Q: Are any of those structural characteristics rare?

A: No.

Q: Are they common?

A: Yes.

Q: Are you able to give the opinion as to the probability of the hair from the brown T-shirt being from the same source as the D-12 sample?

A: I don't understand what you mean by --- I ---

Q: The hair on the brown shirt, that's consistent with the D-12 standard. Can you give an opinion as to the probability whether they're from the same source?

A: No.

Q: All you can say is that it's not impossible that they're from the same source, isn't that correct?

A: That's right.

Q: And if you were given other standards and compared it against that hair from the brown T-shirt, it could be consistent with some or all of those, isn't that right?

A: It's conceivable. Yes.

Note

1. See page 370 of the transcript, <http://www.law.virginia.edu/pdf/faculty/garrett/innocence/avery.pdf>.

NIJ Listening Sessions with Victims and Exonees of Wrongful Conviction

by **Eric Martin** and **Angela Moore**

In February 2016, NIJ and its partners in the Office of Justice Programs and external organizations hosted “Exonees and Original Victims of Wrongful Conviction: Listening Sessions to Inform Programs and Research.” The listening sessions provided a forum for victims or survivors of crimes that resulted in wrongful convictions and for individuals who have been exonerated to share their experiences. The listening sessions were powerful and overwhelming, and the themes that emerged demonstrate the critical need for criminal justice systems to address the unique and largely unmet needs of original victims and exonees of wrongful convictions.

In these sessions, original victims and survivors described the media’s insensitivity, the revictimization of the exoneration process, the lack of victim services compared to what they received during the original prosecution, and the need for peer support. Exonees shared their challenges in transitioning to civilian life, problems with reconnecting with family and friends, difficulties in obtaining a job — or even basic necessities, such as a driver’s license or other identification — and the lack of restitution for their lost wages and Social Security benefits. Both the original victims and exonees expressed frustration with criminal justice systems not being held accountable for wrongful convictions.

Overall, the listening sessions revealed that, currently, there is no systematic response to the needs of original victims and exonees of wrongful convictions. The services offered to original crime victims are inadequate and do not address the revictimization often experienced during the exoneration process. For exonees, there are really no services available, except for those provided to formerly incarcerated individuals re-entering society. Not only are these insufficient, but they are also inappropriate.

Although substantial attention has been devoted to determining the causes of wrongful convictions, there has been limited focus on what happens to victims and exonees when exonerations occur. To address this gap in knowledge, NIJ has commissioned a special report and a mini-documentary on wrongful convictions. The special report describes in detail the themes from the listening sessions and policy recommendations derived from them. The mini-documentary, a companion to the special report, gives some of the victim and exonee participants a chance to share their stories with the public. Learn more at NIJ.ojp.gov, keyword: just wrong.

About the Authors

Eric Martin is a social science analyst in NIJ’s Office of Research and Evaluation. **Angela Moore**, Ph.D., is the division director of the Justice Systems Research Division in NIJ’s Office of Research and Evaluation.

Notes

1. Seri Irazola, Erin Williamson, Julie Stricker, and Emily Niedzwiecki, "Addressing the Impact of Wrongful Convictions on Crime Victims," *NIJ Journal* 274, October 2014, <https://www.nij.gov/journals/274/pages/victim-impact-wrongful-convictions.aspx>; Leslie Scott, "It Never, Ever Ends': The Psychological Impact of Wrongful Conviction," *American University Criminal Law Brief* 5 no. 2 (2010): 10-22, <http://digitalcommons.wcl.american.edu/cgi/viewcontent.cgi?article=1063&context=clb>; and Stephanie Armour, "Wrongly Convicted Walk Away With Scars," *USA Today*, October 13, 2004, at 1A, http://www.usatoday.com/money/workplace/2004-10-13-dna-exonerated-jobs_x.htm.
2. See <http://www.innocenceproject.org>.
3. Jon B. Gould, Julia Carrano, Richard Leo, and Joseph Young, "Predicting Erroneous Convictions: A Social Science Approach to Miscarriages of Justice," Final report to the National Institute of Justice, grant number 2009-IJ-CX-4110, February 2013, NCJ 241839, <https://www.ncjrs.gov/pdffiles1/nij/grants/241389.pdf>.
4. Rebecca Goldin, "Causation vs Correlation," *SENSE about SCIENCE USA*, August 19, 2015, <http://www.senseaboutscienceusa.org/causation-vs-correlation>.
5. See <http://www.law.umich.edu/special/exoneration/Pages/about.aspx>.
6. John M. Collins and Jay Jarvis, "The Wrongful Conviction of Forensic Science," *Forensic Science Policy & Management* 1 no. 1 (2009): 17-31.
7. See <https://www.nist.gov/topics/forensic-science/about-osac>.
8. See <http://www.law.umich.edu/special/exoneration/Pages/casedetail.aspx?caseid=4802>.
9. See <http://www.law.umich.edu/special/exoneration/Pages/casedetail.aspx?caseid=3821>.
10. In comparison, the NRE has a record of 1,944 exonerations (child sex abuse, sexual assault, homicide, and other crimes) and reports that 47 percent are African American, 39 percent are Caucasian, 12 percent are Hispanic, and 2 percent are other races/ethnicities. However, in crimes involving child sex abuse (212 exonerations), 64 percent are Caucasian, 26 percent are African American, and 10 percent are Hispanic.
11. Collins and Jarvis, "The Wrongful Conviction of Forensic Science."
12. Matthew R. Durose, Andrea M. Burch, Kelly Walsh, and Emily Tiry, *Publicly Funded Forensic Crime Laboratories: Resources and Services*, 2014, Bulletin, Washington, DC: U.S. Department of Justice, Bureau of Justice Statistics, November 2016, NCJ 250151, <https://www.bjs.gov/content/pub/pdf/pffclrs14.pdf>.
13. See Katie Mettler, "How a Lab Chemist Went From 'Superwoman' to Disgraced Saboteur of More Than 20,000 Drug Cases," *Washington Post*, April 21, 2017, https://www.washingtonpost.com/news/morning-mix/wp/2017/04/21/how-a-lab-chemist-went-from-superwoman-to-disgraced-saboteur-of-more-than-20000-drug-cases/?utm_term=.a6f589123d19.
14. Tom Jackson, "Mass. Crime Chemist Admits Daily Drug Use in Lab, Sparking a Second Scandal," *The Washington Post*, True Crime section, May 5, 2016, https://www.washingtonpost.com/news/true-crime/wp/2016/05/05/mass-crime-chemist-admits-daily-drug-use-in-lab-sparking-a-second-scandal/?utm_term=.200b64084697.
15. Impression evidence is created when two objects come in contact with enough force to cause an "impression," such as a fingerprint or the marks on a bullet caused by the barrel of a firearm. Pattern evidence may be additional identifiable information found within an impression, such as the examination of shoeprint evidence to identify a particular brand, model, or size (class characteristics). If a shoe is recovered from a suspect that matches this initial pattern, the forensic examiner can also look for unique characteristics that are common between the shoe and the shoeprint, such as tread wear, cuts, or nicks (individual characteristics).
16. See ABFO Bitemark Methodology Guidelines, <http://abfo.org/wp-content/uploads/2012/08/ABFO-Standards-Guidelines-for-Evaluating-Bitemarks-Feb-2018.pdf>.
17. See ABFO ID and Bitemark Guidelines, <https://abfo.org/resources/id-bitemark-guidelines/>.
18. Dr. P.C.H. Brouardel, 19th-century French medico-legalist, quoted in *ASCLD/Lab Guiding Principles of Professional Responsibility for Crime Laboratories and Forensic Scientists*, http://www.identacode.org/ASCLD_Guiding_Principles.pdf.

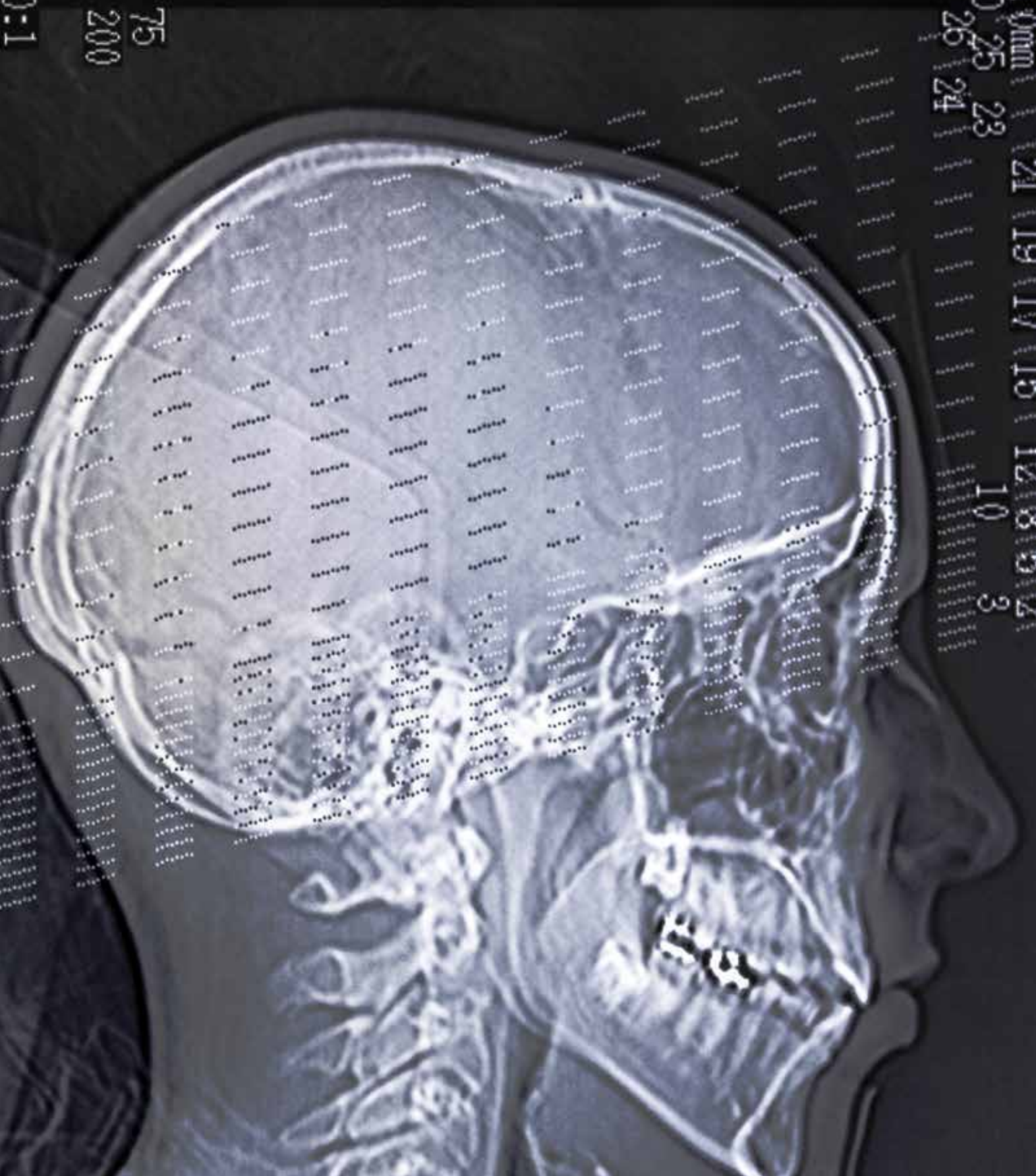
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USING ADVANCED IMAGING TECHNOLOGIES TO ENHANCE AUTOPSY PRACTICES

BY DANIELLE WEISS, DANIELLE MCLEOD-HENNING, AND HEATHER WALTKE

Making imaging technologies available to forensic pathologists as common practice — although not without challenges — will help improve medicolegal death investigations in the United States.

Before x-ray technology, broken bones and bullet location were detected by “physical examination and a doctor’s best guess.”¹ There was no way for a physician to see into the human body without incising it. Then, on November 8, 1895, German physics professor Wilhelm Conrad Röntgen made an astonishing discovery that would forever change diagnostic medicine. While working with high-voltage electricity, cathode rays, and gases at low pressure, he found that “x-rays” could penetrate most solid objects.² For the first time, physicians were able to noninvasively see the human anatomy. Interestingly, Röntgen’s first image was the internal structure of his wife’s hand (see exhibit 1).

In 1895, John Macintyre established the world’s first radiology department at Glasgow Royal Infirmary in Scotland. Early successes included producing the first images of a renal stone. That same year, Walter Bradford Cannon, an American physiologist, used x-rays to follow food passing through an animal’s digestive system.³ In 1896, physicians began to

use x-rays for medicolegal purposes, most often for gunshot cases, tumor identification, and dental examinations.⁴ Over the next 100 years, x-ray technology continued to advance, and imaging helped supplement the scalpel. By the 1980s, Europe saw the early use of virtual or digital autopsies, followed by three-dimensional, multiplanar scans in the early 1990s (see exhibit 2).⁵

Today, using computed tomography (CT) scanning technology — or computerized x-ray imaging⁶ — to augment autopsies is fairly commonplace in Europe, Japan, and Australia. In the United States, however, the practice is not as routine, for reasons we will discuss throughout the article.⁷ In some situations, the use of advanced imaging technologies, such as CT, prior to or in place of a traditional autopsy would be advantageous and could offer solutions to some challenges faced by the medicolegal community, such as limited resources or conditions or circumstances that make the cause of death not easily diagnosed through a traditional (gross anatomy) autopsy. Through research and international partnerships, NIJ is working

Exhibit 1. Röntgen's First X-Ray Image

Note: Wilhelm Röntgen took this radiograph of his wife's left hand on December 22, 1895, shortly after his discovery of x-rays.

Source: Courtesy of the National Library of Medicine.

to inform the community of potential benefits and advance this resource to medical examiners and coroners nationwide.

Many U.S. offices have started to embrace Lodox imaging technology, which is a high-quality, low-dose, digital x-ray that can scan an entire body.⁸ Lodox was invented in South Africa to see if those who work in diamond mines had swallowed diamonds from the mines.⁹ Over time, U.S. trauma centers and medical examiners' offices have incorporated the use of Lodox, which is fast, less expensive than traditional x-rays, and has specific benefits. For example, it can detect specific medical occurrences or features, such as pneumothoraces and bone fractures near the skin's surface, and metal objects such as projectiles and implants. Although Lodox would not replace CT, it is a gateway to new technology. CT technology allows physicians to better visualize areas that are harder to dissect, visualize vessels (including stenosis, occlusion, and ruptures) and stab wounds using radio-opaque dyes, and estimate the volume of hemorrhages.

When an unattended or suspicious death comes to a morgue in the United States, a forensic pathologist — a physician who works as a medical examiner and performs autopsies to determine the cause of death — typically conducts a traditional autopsy. Although we often emphasize the criminal justice or legal aspects of medicolegal investigations, we sometimes forget that medical examiners are physicians who practice medicine; their experience, knowledge, and the tools at their disposal are essential in determining the cause and manner of death.

Meeting the Needs of the Community

About 2.6 million people die each year in the United States; approximately 500,000 of them receive post-mortem examinations.¹⁰ Currently, the nation has a shortage of board-certified forensic pathologists. Projections suggest that 1,000 board-certified forensic pathologists are needed to provide adequate coverage in the United States; however, there are only an estimated 500 full-time forensic pathologists.¹¹ There is a tremendous need to develop and implement advanced methods that could not only enhance autopsies diagnostically but also help combat this shortfall and reduce workloads.¹²

For example, burn victims and motor vehicle fatalities can sometimes present with injuries that are difficult to discern due to the condition of the body. Imaging technology, such as CT, could help pathologists evaluate these cases more quickly without needing to complete a time-consuming gross autopsy. A CT radiograph might offer the pathologist a clear and apparent cause of death without conducting a full autopsy. Another significant advantage to using imaging technology is that the pathologist never loses the ability to delve further if a case requires additional investigation — the use of imaging does not impede the option of going back to a traditional autopsy to supplement findings.

The question of who examines and evaluates CT radiographs can present a potential challenge, as pathologists currently do not perform these duties. However, this is not an unmanageable concern.

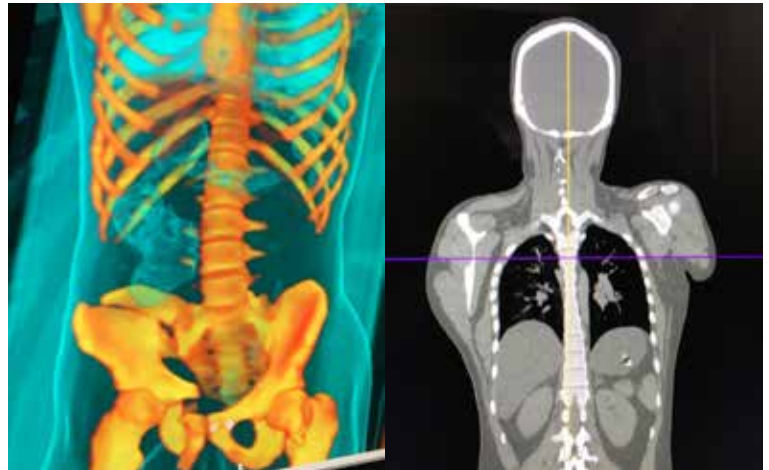
First, medical examiners' and coroners' offices can supplement their staff with radiologists, who can triage and manage a portion of their office's caseload. Pathologists can also be trained to review radiographs, which may assuage the need to hire additional staff. Some of the offices' cases might then be resolved quickly through imaging, thus realizing significant time savings. More importantly, because forensic pathologists are experienced in examining the deceased, they are in a better position to interpret the nuances of post-mortem change, such as interpreting what is an actual injury versus what may be imaging artifacts or changes due to decomposition or insect predation; hospital pathologists do not have such experience or exposure.¹³

Additionally, CT may allow medical examiners to better meet the needs of families. Some groups may object to a traditional autopsy because of religious or cultural considerations (e.g., those who are Jewish, Muslim, and Native American).^{14,15} In these circumstances, CT offers a noninvasive alternative that will avoid distressing a family further during a difficult time. Some cultures also have traditions regarding the expediency of burial timeframes; imaging would allow the pathologist to resolve a case within such customary requests. Further, from a medicolegal perspective, imaging might be the only diagnostic tool available to the pathologist to determine the cause of death, as some state laws prevent a medical examiner from performing an autopsy over a family's objection.¹⁶

Imaging might also enable nationwide collaboration through telemedicine and technical reviews, especially in regions of the country that lack medical examiner services. In addition, if a case moves to the prosecutorial stage, use of CT-type images as courtroom exhibits may be more palatable to judges and juries than gross anatomy photos showing massive or severe injury.

Making imaging technology available to pathologists as common practice will take effort and persistence. The use of advanced imaging techniques offers agencies a way to reduce the number of gross autopsies needed, address the shortage of forensic

Exhibit 2. Three-Dimensional Scan and CT Scan



Note: The image on the left is a three-dimensional rendering of a torso showing hip fractures; the image on the right is a CT scan of a torso on a coronal plane. The images were viewed through a program called OsiriX, <http://www.osiriX-viewer.com>.

Source: Photos taken by Danielle McLeod-Henning (NIJ) at the University of New Mexico (2016).

pathologists, decrease the number of biohazard exposures, honor our nation's diverse cultural traditions, and, most importantly, increase the amount of diagnostic information that is captured and retained electronically. Unfortunately, the use of CT is not commonplace in much of the United States, for many reasons, including the cost and maintenance of CT equipment, the lack of temperature-controlled facilities with adequate structural integrity, lack of access to and availability of experienced individuals who are able to read and interpret CT images, and the need for additional research. These challenges are not insurmountable and the benefits far outweigh the burdens; it is important to identify solutions and find a way to achieve practical application and cost-effective implementation in this country.

Old Technology, New Practice

Some U.S. agencies have made great strides in bringing CT technology to their medicolegal community. For example, four agencies in this country have in-house CT scanning equipment. The Armed Forces Medical Examiner's Office (AFMEO), located in Dover, Delaware, focuses solely on U.S. servicemen

and servicewomen. AFMEO scans every decedent who comes through its morgue and is using fellowships to advance training in this area. The Chief Medical Examiner's Office in Maryland also has a CT scanner, which it uses in about half of its cases each year; a radiologist works with the medical examiner and provides consultation.¹⁷ The New Mexico Office of the Medical Investigator (NMOMI) and the Los Angeles County Coroner/Medical Examiner also have in-house CT scanning equipment that has been very effective in daily practice.¹⁸

Creating Global Partnerships

NIJ is working to advance imaging technology for medical examiners and coroners nationwide. For example, NIJ currently supports cutting-edge research¹⁹ being conducted at the University of New Mexico Health Sciences Center²⁰ and hosted a technology transition workshop²¹ at NMOMI through its Forensic Technology Center of Excellence.²²

In collaboration with the Netherlands Forensic Institute (NFI), NIJ created and shaped the International Forensic Radiology Research Summit (IFRRS), an international working group looking to establish a research agenda of high-priority needs concerning advanced imaging technologies for forensic pathology applications. In 2011, NIJ entered into a memorandum of understanding with NFI and the Netherlands Organisation for Scientific Research, Chemical and Physical Sciences Division, to advance cooperation and information sharing for the development of effective solutions and priorities that will improve forensic science and criminal justice research. NIJ and NFI identified a mutual need focusing on research and practice in forensic radiology. In 2015, NIJ, NFI, and leadership from the Joint Congress of the International Society for Forensic Radiology and Imaging (ISFRI) and the International Association of Forensic Radiographers (IAFR) began preparations to convene a working group of professionals in forensic radiology to produce a road map to address gaps, challenges, and research needs in the field. On May 10-11, 2016, the IFRRS was held at the Academic Medical Center in Amsterdam, in conjunction with the ISFRI and the IAFR.

Research-Guided Solutions

The IFRRS, spearheaded by NIJ and NFI and with the support of the ISFRI and the IAFR, brought together 40 leading researchers, practicing medical and forensic professionals, and government employees from 11 countries²³ to build research partnerships, encourage collaborations in the global community of forensic radiology, address challenges, and identify possible solutions for the implementation of advanced imaging technologies in medicolegal practice. During the two-day meeting, Dr. Gregory G. Davis, chief coroner/medical examiner in Jefferson County, Alabama, facilitated a discussion with the expert working group that focused on developments and challenges in implementing forensic radiology techniques and research priorities. The expertise and leadership offered by the working group produced a series of priority areas, including but not limited to big data and statistics, age estimation and reconstruction, multimodal imaging, and visualization and presentation.²⁴

Using big data to enhance research

Many countries have a common desire to perform research. However, not all countries have the same access to relevant data, as the prevalence of crime affecting their communities may not be equal in volume. The working group noted that an agency's caseload might be insufficient to conduct a statistically relevant study and recommended that an international clinical and forensic reference database be created for medicolegal research purposes.²⁵ For instance, many countries do not have the same prevalence of gun violence as that found in the United States, and a collaboration with the United States might provide a larger data set that could potentially offer results with greater statistical significance.

Additional research is needed to collect data and solidify the effectiveness of imaging within certain populations, such as pediatric and elder abuse cases. Research would also help propel the practice forward through the development of machine-driven, automated image assessments, which, up until now,

have demonstrated poor results. Big data sets might also provide a robust evaluation pool to assess the skills of radiologists compared to other experts, which might lead to better training protocols to improve techniques and procedures when dealing with decedents.

Profile characteristic estimation and scene reconstruction

The working group also discussed age estimation and reconstruction. Population frequencies and variation, extrapolated from biological profiles, are used to better estimate age, sex, stature, and ancestry. Additional research is needed to further support the data and strengthen biological profile assessment.

Innovative use of technology would be valuable to identify victims of disasters, particularly in situations in which fingerprint collection is unavailable or DNA collection is too risky due to scene hazards. For instance, mobile scanning technology could capture images of body position to preserve the orientation of injuries; the United Kingdom has been using portable scanners for several years.²⁶ Clinical radiology and imaging used in diagnostics are also well established; however, the working group noted that further research is needed when applying these techniques to post-mortem investigations.

Multimodal imaging

Combining traditional methods with novel techniques — referred to as “multimodal approaches” — can provide pathologists with a more detailed picture. For example, the combination of magnetic resonance imaging (MRI) and near-infrared optical spectroscopy has been used successfully to identify malignant and benign breast tumors.²⁷ CT/MRI data that date injuries in living patients over time could be compared with scans of the deceased to more accurately identify and date ante- and post-mortem injuries and identify changes (e.g., those caused by decomposition). Although MRI and near-infrared optical spectroscopy are not commonly used by medical examiners, opportunities for growth and research into these new areas should be considered.

Demonstrative aids and presentation in court

Using visual aids to present evidence in court is incredibly important. In homicide cases, the expert opinions and exhibits provided by the medical examiner are invaluable. More robust research is needed that supports how to better and more reliably portray visual aids and how to properly present to the jury what scenarios align with the evidence. For example, animations are based on theory rather than documentation, and it is difficult to get animations admitted into court. In contrast, radiological scans are already used in court to depict injury, eliminating the need to show inflammatory photographs to the jury. However, currently no research addresses quantifying the utility of demonstrative aids and illustrations used in court; evidence-based data of this type would be extremely beneficial to the criminal justice system.

Looking Ahead

Although there are challenges in transitioning advanced imaging technologies (such as CT) into medical examiners' and coroners' offices, continued research will provide a better understanding of the applications and limitations of advanced imaging for forensic pathology. The benefits could likely offset many challenges faced by forensic pathologists (such as cultural or religious objections), alleviate the volume of cases, and allay efforts to complete all cases through gross autopsy. Furthermore, advanced imaging technologies in forensic pathology could improve courtroom displays, facilitate telemedicine, and provide a permanent objective data archive.²⁸ Imaging could be used as a complementary tool. Other technologies, such as Lodox, could also be considered — not in place of CT, but to augment medicolegal practice beyond traditional x-rays. Forensic pathologists need access to investigative tools that will ensure decedents are given equal care to the living and that medical examiners are providing robust information to the criminal justice community.

Continued collaborations, information sharing, technology transition, and support of a robust research agenda in advanced imaging for forensic pathology will serve to improve medicolegal death investigations in the United States.

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For More Information

Learn more about NIJ's work at NIJ.ojp.gov, keyword: autopsy.

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- "Investigation of the Impact of Body Temperature and Post-Mortem Interval on Magnetic Resonance Imaging (MRI) of Unfixed Tissue," grant number 2012-DN-BX-K019
 - "Investigation of Post-Mortem Magnetic Resonance Imaging for the Detection of Intraneural Hemorrhage," grant number 2013-DN-BX-K004
 - "Evaluation of the Routine Use of CT Scanning to Supplement or Supplement Autopsy in a High-Volume Medical Examiner's Office," grant number 2016-DN-BX-K002
 - "Improving and Evaluating Computed Tomography and Magnetic Resonance Imaging in the Investigation of Fatalities Involving Suspected Head Trauma," grant number 2016-DN-BX-0173
 - "Facilitating Forensic Research in Multiple Fields Using a Unique Computed Tomography Dataset," grant number 2016-DN-BX-0144
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SEXUAL ASSAULT CASES: EXPLORING THE IMPORTANCE OF NON-DNA FORENSIC EVIDENCE

BY **HEATHER WALTKE, GERALD LAPORTE, DANIELLE WEISS, DAWN SCHWARTING, MINH NGUYEN, AND FRANCES SCOTT**

Investigating and prosecuting sexual assault crimes is much more complicated than simply performing DNA testing.

After an evening of hanging out with friends, a 20-year-old woman decided to get a ride home with her ex-boyfriend. They had broken up several months before but had remained friendly with each other. During the drive, the young man started talking about how they should get back together because he missed the relationship they once had. However, she was not interested and wanted to remain friends.

Only blocks from her home, the man stopped the car and suddenly turned violent. Grabbing her neck, he began to force himself on her. As he ripped off her clothes, she managed to grab a small pocket knife from her purse, but he took the knife from her and broke it. He then dragged her by the legs out of the car and raped her in a nearby wooded area. Afterwards, he stole her credit cards and drove away. The woman managed to walk to her home and called the police to report the rape. She was brought to the

hospital, where she was interviewed, photographed, and examined for several hours. Evidence was collected for a sexual assault kit (SAK).

To many, this would seem like a clear-cut case of sexual assault. However, a case is not determined by what one believes, but rather by what the investigation shows and what can be proved.

When the police spoke with the young man, he described a very different series of events. He claimed that he and his ex-girlfriend had a fun evening at the party and that she came on to him and wanted to get back together. He admitted to taking some drugs that evening and thought he blacked out briefly. When he woke up, he claimed that his ex-girlfriend was on top of him and they had consensual rough sex. He said their clothes were everywhere, and he must have accidentally taken her credit cards when he gathered his things. He denied ever handling a knife.

In cases in which probative DNA evidence is not readily available or offers little or no meaning, an accumulation of non-DNA forensic evidence can be what ultimately leads to a successful conviction.

So what really happened that evening? In a case like this of “he said, she said,” investigators look to the forensic evidence to help them piece together what may have actually happened. The investigation and exploration of the totality of the evidence collected are critical to unravelling the allegations and discerning whether charges can be filed.

DNA Is Not Always Probative or Present

DNA analysis has had an unprecedented impact on the criminal justice system. It has propelled investigations forward and made charging alleged perpetrators easier. Science can now provide focus or direction to an investigation, help develop a case theory, and clear suspects or those wrongfully convicted with more certainty. As a result, the criminal justice community has become highly reliant on DNA analysis.

Many believe DNA analysis is the death knell for most criminal defendants, and juries and lawyers alike *expect* to see DNA evidence presented during a trial.¹ It has been reported that 72 percent of jurors anticipate seeing DNA in a sexual assault trial² and that juries are 33 times more likely to convict when presented with DNA evidence.³ This raises serious concerns, as the need to provide probative DNA evidence in sexual assault cases has become increasingly more important if a prosecutor hopes to secure a conviction.

But what happens in a “he said, she said” case like the one described above, where the alleged suspect

is not a stranger and, in fact, admitted to having sexual intercourse? In a random sampling of 602 reported rapes, 36.2 percent were among intimates or family members and 42.7 percent were friends or acquaintances.⁴ In such cases where the suspect and victim are acquainted, consent is pivotal to determining whether a crime was committed, and the presence of the suspect’s DNA may not necessarily be informative.⁵

Or what about cases in which no DNA is found? Recently, a great deal of attention has been placed on testing SAKs, especially those collected years ago and never submitted to a forensic laboratory. Although testing SAKs for DNA is important, the reality is that DNA is sometimes not found or is not eligible for entry into the Combined DNA Index System (CODIS),⁶ which is composed of databases maintained by the Federal Bureau of Investigation that allow DNA profiles to be compared to one another. For example, to be uploaded into CODIS, DNA profiles must meet certain quality standards, and sometimes the DNA is old, degraded, not in sufficient quantity, or otherwise unviable. Additionally, the sample may not be directly probative (such as in cases in which the alleged perpetrator admitted having sexual contact).⁷ Based on NIJ’s SAK-related projects (see exhibit 1), DNA profiles that were of sufficient quality for CODIS upload were obtained in only 38 percent of more than 7,000 SAKs submitted for DNA testing.⁸ Also, performance metrics collected from NIJ’s Solving Cold Cases with DNA program showed that about 48 percent of the cases with tested biological evidence yielded any DNA profile.⁹ NIJ’s results are consistent with other national findings. For example, a recent South Dakota SAK project that tested 504 kits yielded only 254 DNA profiles,¹⁰ and half of the 3,542 kits tested in a Colorado project yielded DNA profiles.¹¹

As new and emerging technologies advance across the criminal justice system and provide necessary links for locating and apprehending assailants, criminals continue to learn about forensic science techniques and have started to “get smart.” Many sex offenders, for example, now use gloves, masks, and

Exhibit 1: Data From NIJ SAK Programs

Study	Number of SAKs Tested	Number of CODIS Entries	% of Profiles Eligible for CODIS Entry	CODIS Hits	CODIS Hits/CODIS Entries (%)	CODIS Hits/Total Number of SAKs (%)
Los Angeles ¹	1,948	699	36%	347	50%	18%
Detroit ²	1,595	785	49%	455	58%	29%
New Orleans ³	1,008	256	25%	139	54%	14%
Houston ⁴	491	213	43%	104	49%	21%
FBI (as of 1/5/2017) ⁵	1,584	808	51%	306	38%	19%
Marshall (as of 10/5/2016) ⁶	588	149	25%	39	26%	7%
Total	7,214	2,910		1,390		
Average			38%		46%	18%

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condoms, and some even have a victim shower before they leave a scene — all in the hope of thwarting law enforcement’s ability to collect potential DNA evidence. Take, for example, the case of Colorado serial rapist Marc O’Leary, who committed several sexual assaults in multiple jurisdictions. He ordered

women to shower and brush their teeth, and he took the bedding and clothing with him. However, he executed his crimes with the same *modus operandi*, leaving behind shoe prints, glove pattern evidence, and other non-DNA evidence that was used to connect him to the crime scenes.¹²

Non-DNA forensic evidence can be used to identify a suspect, associate a suspect with a victim, associate a suspect with a crime scene, and corroborate other evidence.

The Value of Non-DNA Evidence

In cases in which probative DNA evidence is not readily available or offers little or no meaning to the allegations being made, an accumulation of non-DNA forensic evidence can be what ultimately leads to a successful conviction.

A wealth of other forensic evidence may be invaluable in sexual assault investigations; some examples are trace evidence (e.g., hairs, fibers, glass, paint, or soil), toxicology, cell phone and digital forensics, and impression and pattern evidence (e.g., fingerprints, shoe prints, tire marks, and handwriting). One study showed that in addition to bodily fluids, fingerprints and hairs are the most common types of physical evidence collected and examined in sexual assault casework.¹³ The Bureau of Justice Statistics also reported that from 2005 through 2010, sexual assault offenders were armed with a gun, knife, or other weapon in 11 percent of rape or sexual assault victimizations.¹⁴ All of these types of non-DNA forensic evidence can be used to identify a suspect, associate a suspect with a victim, associate a suspect with a crime scene, and corroborate other evidence.

Based on the evidence identified and collected during the sexual assault investigation in our case example, the knife was tested and contained prints of both the victim and the suspect, even though the suspect denied handling the knife. The young woman had no alcohol in her system, and the medical exam showed she had cuts, bruises, and tears to her body and genitals — 33 documented injuries. Her clothing was torn and her pants zipper was broken. Toxicology results revealed that the suspect tested

positive for methylenedioxy-methamphetamine (MDMA, commonly known as Ecstasy), a drug that is known to produce feelings of increased energy, pleasure, and distorted sensory and time perception. The investigation also revealed that the suspect sent the victim text messages in the days after the assault, even though he denied having any contact with her.

Therefore, when DNA is not available or not probative, other forensic evidence can help establish the facts. The most important take-away is that a case should be developed using the totality of the evidence rather than relying solely on DNA, which allows one to recreate an entire series of events; corroborate or refute testimony from the victim, suspect, or other witnesses; and ultimately include or exclude a potential suspect. Based on the accumulated evidence described in this case scenario, criminal charges would likely result,¹⁵ as there is evidence showing injury and violence, corroboration of the victim's account of the attack, and evidence that would disprove aspects of the suspect's version of events.

Prosecutors also rely on scientific evidence to establish and prove their cases during prosecution. Research has shown that “analysis of forensic evidence was associated with [increased] case referrals to prosecutors, [and] charges filed.”¹⁶ Evidence from a medical forensic exam can be key in the prosecution of a sexual assault case. A study conducted in 1999 found a relationship where the victims' injuries were seen as one of the most significant predictors in the decision to prosecute in nonstranger cases.¹⁷ The presence of injuries seemed to influence a prosecutor's decision-making, as the documented appearance of violence makes it more difficult to assert consent.

The presence of forensic evidence also strengthens the likelihood of conviction at trial and has been associated with harsher sentences.¹⁸ Prosecutors are better able to recreate events and illustrate a theory to a jury by connecting testimonial evidence and forensic evidence. More specific to sexual assault cases, research has indicated that cases with physical evidence were more likely to lead to arrest, be referred to the prosecutor, be charged, and result in

Drug Facilitated Sexual Assaults

Drug-facilitated sexual assaults (DFSA) are increasing nationwide, especially among college-age women.¹ Alcohol and drugs are common contributors to sexual assault, especially assaults committed by acquaintances, because they can cause diminished capacity and make a person vulnerable to their surroundings. Depending on the drug, effects can be felt as quickly as 20 minutes after ingestion and can cause amnesia for up to 8 hours. Whether a “date-rape” drug such as alprazolam (Xanax) or gamma-hydroxybutyric acid (GHB) is unknowingly ingested or a mainstream party drug such as alcohol, methylenedioxy-methamphetamine (Ecstasy), or marijuana is used voluntarily, the identification of these substances through toxicological testing may offer a jury compelling evidence indicating a victim’s inability to have consented to the advances of an alleged assailant.²

Ensuring that toxicological testing is completed in a timely manner³ is paramount due to the rapid metabolic process and excretion rates of many drugs.⁴ NIJ is currently supporting research to explore new ways of extending the testing window to allow drugs to be detected days or even weeks after ingestion.⁵ This novel research is looking at complexes formed between proteins in the blood and the drug, which remain in the blood for weeks after ingestion. This could offer evidence of a victim’s incapacitation in cases where reporting of the assault is delayed.

Toxicological testing is complicated by the emergence over the past decade of “designer” drugs, which may not be detectable using a lab’s usual methods.⁶ NIJ-supported research has also confirmed that many of these drugs break down very rapidly in blood or urine, even in samples that have already been collected and refrigerated or frozen, as they would be in a suspected DFSA case.⁷ Drugs also are broken down into metabolites by the body, and little is known about the metabolites of these new drugs. Often, these metabolites are present at higher levels than the original drug, so it is critical to be able to identify them if present in the body of a DFSA victim. NIJ is committed to supporting research to identify these metabolites, determine which new drugs are being abused, and develop new methods for identifying these emerging drugs.⁸

Notes

1. Steven Lawyer et al., “Forcible, Drug-Facilitated, and Incapacitated Rape and Sexual Assault Among Undergraduate Women,” *Journal of American College Health* 58 no. 5 (October 2010): 453-460, <http://www.tandfonline.com/doi/abs/10.1080/07448480903540515>. Recent news reports describe incidents on college campuses such as the

continued on the next page

conviction than cases without evidence.¹⁹ Sometimes the availability or admission of forensic evidence, merely to show its existence, can be essential as well. Regardless of the context or support the evidence may offer to a case, juries continue to expect personally identifying forensic evidence; for example, Ric Ridgway, chief prosecutor for the 5th Judicial Circuit in Central Florida, received feedback from jurors after

an acquittal asserting, “Well, there wasn’t any DNA or fingerprints.”²⁰

The Need for Research and Innovative Non-DNA Forensic Methods

Countless types of forensic evidence are used to investigate and prosecute thousands of crimes

Drug Facilitated Sexual Assaults (continued)

University of Missouri (UM) and Northwestern University where fraternities were using date-rape drugs at parties and for initiations. At UM, the Delta Upsilon fraternity initiation process allegedly required new members to drug women in order to incapacitate them and engage in sexual activity. The fraternity is even alleged to have supplied the drugs. These examples are not unique; a 2015 study from the University of Pennsylvania notes that 6 percent of the students were sexually assaulted while they were incapacitated. Claire Landsbaum, "University of Missouri Fraternity Allegedly Forced New Members to Give Women Date-Rape Drugs," *The Cut*, October 14, 2016, <https://www.thecut.com/2016/10/missouri-fraternity-allegedly-gave-out-date-rape-drugs.html>; Joe Sterling, "Sex Assault, Date-Rape Drug Allegations Rattle Northwestern," *CNN Wire*, February 7, 2017, <http://www.cnn.com/2017/02/07/us/northwestern-date-rape-drug-reports/index.html>; and David Cantor et al., *Report on the AAU Campus Climate Survey on Sexual Assault and Sexual Misconduct* (New York: Association of American Universities, 2015), https://www.aau.edu/sites/default/files/%40%20Files/Climate%20Survey/AAU_Campus_Climate_Survey_12_14_15.pdf.

2. State laws define consent differently, but some factors to consider are age, disability, intoxication, and unconsciousness. "Legal Role of Consent," *Rape, Abuse & Incest National Network*, <https://www.rainn.org/articles/legal-role-consent>.
3. A Sexual Assault Evidence Collection Program through the Massachusetts Executive Office of Public Safety and Security supplies a toxicology kit to test for the presence of substances as part of their SAK; however, toxicology testing in Massachusetts is conducted only within 96 hours of the assault. Theodore P. Cross et al., "Forensic Evidence and Criminal Justice Outcomes in a Statewide Sample of Sexual Assault Cases," Final report to the National Institute of Justice, grant number 2011-WG-BX-0005, September 2014, NCJ 248254, <https://www.ncjrs.gov/pdffiles1/nij/grants/248254.pdf>.
4. Some drugs are no longer in the blood after 4-6 hours; others can remain in the urine up to 48 hours because of the way the body metabolizes the substance. "Drug Facilitated Sexual Assault," *West Virginia Foundation for Rape Improvement Services*, <http://www.fris.org/SexualViolence/DrugFacilitated.html>.
5. Richard A. Gilliland, Carolina Moller, and Anthony P. DeCaprio, "Liquid Chromatography/Tandem Mass Spectrometry (LC/MS/MS) -Based Analysis of *In Vitro* Covalent Modifications of Glutathione (GSH) and Peptide Thiols by Drugs of Abuse," proceedings of the 69th Annual Scientific Meeting of the American Academy of Forensic Sciences, New Orleans, LA, February 2017, <https://www.aafs.org/wp-content/uploads/2017Proceedings.pdf>.
6. Anthony P. DeCaprio, W. Lee Hearn, and Madeleine J. Swortwood, "Comprehensive Forensic Toxicological Analysis of Designer Drugs," Final report to the National Institute of Justice, grant number 2011-DN-BX-K559, December 2013, NCJ 244233, <https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=266314>.
7. Lindsay Glicksberg, Kelsie Bryand, and Sarah Kerrigan, "Identification and Quantification of Synthetic Cathinones in Blood and Urine Using Liquid Chromatography-Quadrupole/Time of Flight (LC-Q/TOF) Mass Spectrometry," *Journal of Chromatography B* 1035 (2016): 91-103; and Megan Grabenauer, Katherine N. Moore, and Brian F. Thomas, "Characterization of Designer Drugs: Chemical Stability, Exposure, and Metabolite Identification," Final report to the National Institute of Justice, grant number 2012-R2-CX-K001, April 2016, NCJ 249855, <http://www.ncjrs.gov/App/publications/abstract.aspx?ID=272015>.
8. Amanda L.A. Mohr, Melissa Friscia, and Barry K. Logan, "Identification and Prevalence Determination of Novel Recreational Drugs and Discovery of Their Metabolites in Blood, Urine and Oral Fluid," Final report to the National Institute of Justice, grant number 2013-DN-BX-K018, October 2016, NCJ 250338, <http://www.ncjrs.gov/App/publications/abstract.aspx?ID=272498>; Alex J. Krotulski, Amanda L.A. Mohr, Melissa Friscia, and Barry K. Logan, "Application of SWATH™ Acquisition for Broad Based Forensic Toxicology Drug Screening of Oral Fluid Using Liquid Chromatography Quadrupole Time-of-Flight Mass Spectrometry (LC-QTOF)," poster presentation to the Society of Forensic Toxicologists, October 2016, http://www.soft-tox.org/files/meeting_abstracts/SOFT_2016_meeting_abstracts.pdf; and Sarah Kerrigan, "Designer Amphetamines in Forensic Toxicology Casework," Final report to the National Institute of Justice, grant number 2008-DN-BX-K126, March 2013, NCJ 241439, <https://www.ncjrs.gov/pdffiles1/nij/grants/241439.pdf>.

annually. According to the Bureau of Justice Statistics, in 2014 the nation's 409 crime labs received an estimated 3.8 million requests for forensic services. Only 9 percent of these requests were for forensic biology casework such as from a crime scene (which includes DNA testing), and 24 percent were for DNA analysis of reference samples collected from convicted offenders and arrestees that were then added to the national database.²¹ This means 67 percent of the total requests were solely for non-DNA forensic analysis.

Exhibit 2 illustrates the types of evidence analysis requested from publicly funded laboratories between 2009 and 2014. Clearly there is a demand for non-DNA forensic evidence. Toxicology testing, or the identification of drugs or other chemicals in the human body, was the third most requested of all forensic evidence, after forensic offender/arrestee DNA sample testing. Controlled substance analysis of drugs or chemicals regulated by the government, such as cocaine, heroin, marijuana, or certain prescription drugs, was first.

Toxicological analysis has become critical in the prosecution of drug-facilitated sexual assault cases as another way to nullify an assertion of consent. To further advance science and ensure that evidence can be identified and used appropriately, NIJ supports and funds a diverse portfolio of forensic science research to develop highly discriminating, accurate, reliable, cost-effective, and rapid methods for the identification, analysis, and interpretation of physical evidence for criminal justice purposes. (See sidebar, "Drug-Facilitated Sexual Assaults.")

Fingerprint evidence can be instrumental when trying to place a person at a crime scene, such as from the knife used during the assault in the opening case scenario. As seen in exhibit 2, requests for fingerprint analysis have only increased. Other than DNA, fingerprints are one of the most common types of evidence that can link a perpetrator to an assault. NIJ has a rich research and development portfolio focused on new technologies related to the development of latent prints, as well as studies related to the accuracy

and reliability of fingerprint examinations.²² (See sidebar, "What You Can't See Might Solve the Case.")

In certain cases of sexual assault, chemical examination of condom lubricants may also prove surprisingly valuable, as many assailants are serial perpetrators and routinely use condoms to avoid leaving DNA evidence. NIJ recently funded a project at the University of Central Florida to improve the characterization and classification of condom lubricants recovered in sexual assault cases and build databases of lubricant mass spectra and infrared spectra that will be available for use in casework.²³ This type of analysis can help determine if the perpetrator used a condom and, in some cases, forensic scientists can compare the lubricant recovered from the victim with condoms seized from the suspect.

Additionally, analyzing the various materials used during an assault can provide important information; for example, physically matching a piece of tape collected from a bound victim with evidence recovered from a suspect. Recognizing that duct tape is commonly used in abductions, homicides, and the construction of explosive devices, NIJ provided funding for researchers at the University of California, Davis to perform a statistical evaluation on matching the torn and cut ends of duct tape. They examined 1,800 torn tape specimens and 400 cut tape specimens and concluded that the mean accuracy for correctly matching specimens ranged from 98.58 to 100 percent for torn tape and from 98.15 to 99.83 percent for cut tape.²⁴ NIJ also awarded Florida International University a grant to evaluate and validate the scientific reliability of chemical methods for profiling tapes. Using a collection set of more than 250 tapes (duct and electrical), researchers are applying rigorous analytical methods to examine the variations within and between rolls of tape to understand the relation to tape manufacturing and distribution.²⁵

Finally, body fluid identification of stains (such as differentiation of semen, saliva, vaginal fluid, and menstrual blood) can be critical in identifying

Exhibit 2: Requests for Services Received and Completed by Publicly Funded Forensic Crime Labs, by Type of Request, 2009 and 2014

Type of Request	Received				Completed			
	2009		2014		2009		2014	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
All requests	4,020,000	100%	3,783,000	100%	3,830,000	100%	3,646,000	100%
Controlled substances	1,358,000	34	1,265,000	33	1,261,000	33	1,197,000	33
Crime scene	188,000	5	171,000	5	188,000	5	170,000	5
Digital evidence	33,000	1	25,000	1	33,000	1	24,000	1
Firearms/toolmarks	147,000	4	154,000	4	132,000	3	142,000	4
Forensic biology casework	260,000	6	333,000	9	239,000	6	296,000	8
Forensic biology from convicted offender/arrestee samples	1,053,000	26	908,000	24	1,027,000	27	904,000	25
Impressions	11,000	--	7,000	--	11,000	--	7,000	--
Latent prints	270,000	7	295,000	8	274,000	7	301,000	8
Questioned documents	13,000	--	9,000	--	12,000	--	9,000	--
Toxicology	629,000	16	566,000	15	606,000	16	554,000	15
Trace evidence	58,000	1	49,000	1	47,000	1	41,000	1

Note: Totals exclude requests outsourced to other labs. The number of requests completed in 2009 and 2014 exceeded the number of requests received during that year for certain disciplines because the completed requests included some requests received prior to that year. Numbers are rounded to the nearest thousand. Detail does not sum to total due to rounding.

--Less than 0.5 percent.

Source: Bureau of Justice Statistics, Census of Publicly Funded Forensic Crime Laboratories, 2009 and 2014.

What You Can't See Might Solve the Case

Latent fingerprints hold the potential to associate an individual perpetrator with high probability to a crime scene. In 1991, a 78-year-old widow, Lucille Johnson, was attacked and severely beaten in her home. Johnson died at the scene due to multiple blunt force injuries, and several personal possessions were missing. Through an NIJ Solving Cold Cases with DNA award,¹ the jurisdiction of Unified Police of Greater Salt Lake was able to reexamine the case records and evidence associated with Johnson's homicide.

As a result, a CODIS match identified John Sansing as the contributor to a DNA sample recovered from evidence associated with the homicide. However, in addition to the DNA evidence, the cold case detectives noted that investigators recovered Lego building blocks from the scene. Johnson's family insisted that she was a meticulous housekeeper and would not have left the toys out unless one of her grandchildren had visited.

The suspect was currently incarcerated for the brutal death of a social worker who was bringing supplies to the suspect's family. Particularly disturbing is that he sexually assaulted and killed the social worker in the presence of his young children. Johnson's family stated that she would not have let a stranger into her house unless perhaps the stranger had a child, such as Sansing's then 5-year-old son. Using this information, detectives compared and matched the fingerprints found on the Lego blocks to the now-adult son of the suspect. The fingerprints on the Legos and the DNA CODIS match led to the arrest of John Sansing for the murder of Lucille Johnson. Sansing pled guilty to the Utah homicide; he is still incarcerated in Arizona and sentenced to death for the social worker's homicide.²

Notes

1. National Institute of Justice, "Solving Cold Cases with DNA" award to the Unified Police of Greater Salt Lake, grant number 2012-DN-BX-K029, 2012.
2. Colleen Curry, "Lego Fingerprints Helped Solve Cold Case Murder," *ABC News* (August 29, 2014), <http://abcnews.go.com/US/lego-fingerprints-helped-solve-cold-case-murder-authorities/story?id=25178331>.

probative evidence and corroborating the events of an assault. Serological methods used for body fluid identification can provide more meaningful information about the nature of the crime. Even in the absence of definitive DNA results, confirmation for the presence of body fluids — semen or saliva, for example — in a victim or on a particular piece of evidence may prove significant in building a case or corroborating events. This evidence may provide a prosecutor with the source attribution information needed to connect specific forensic evidence with testimonial accounts. For example, if a victim asserts that an assailant bit her neck and ejaculated on her jeans, the body fluid

identification process would allow one to assert that the fluid collected from the victim's neck was saliva and biological material on the victim's clothing was, in fact, semen and not from casual contact.²⁶ Body fluid evidence can also be significant in instances where a suspect states that the presence of blood was a result of consensual sex with a partner in menses. In these cases, identification of the stain as venous blood might refute this claim and instead support that a violent act had occurred.

As with all science, body fluid identification can be advanced. For example, the power to more

Body Fluid Identification

Methods used to examine sexual assault evidence — such as the use of an alternate light source (e.g., ultraviolet light) to visually detect semen stains, histological microscopic examination to observe spermatozoa, chemical methods based on the detection of seminal fluid acid phosphatase, and immunological methods based on the detection of p30 (or prostate-specific antigen) — have been described in scientific literature for more than three decades. Other common body fluids for which presumptive identification methods are routinely employed include blood and saliva. Such methods are typically based on the detection of hemoglobin (blood) through a phenolphthalein (Kastle-Meyer) test and the detection of saliva through an α -amylase test. Regardless of whether serological tests are performed as a screening step prior to DNA testing or to provide additional substantive case information after DNA testing, they are instrumental tools for forensic investigators.

Technology companies continue to develop new kits and tools to make body fluid identification more discriminatory, faster, and less labor intensive. More recent commercial advances boast the ability for multiplex testing to identify multiple body fluids simultaneously in a relatively short amount of time.

Meanwhile, NIJ continues to fund innovative research to address the need for new tools to better identify body fluids while minimizing the consumption of evidence. With NIJ funding, spectroscopic methods used in other analytical chemistry applications are being applied to forensic science to develop new methods. Attenuated total reflection (ATR) Fourier transform infrared (FT-IR) spectroscopy has the potential for nondestructive blood stain analysis in laboratory and crime scene settings.¹ Raman spectroscopy coupled with chemometrics has been shown to be able to discriminate between peripheral blood, menstrual blood, saliva, semen, sweat, and vaginal fluid, without consuming any sample.² Advances are also being made in surface-enhanced Raman spectroscopy for the identification of dried blood, semen, vaginal fluid, saliva, and urine.³ NIJ funds are also being used to develop multiplex methods to identify multiple body fluids (e.g., human saliva, urine, seminal fluid, vaginal fluid, peripheral blood, and menstrual blood) using mass spectrometry.⁴ As forensic laboratory interest in massively parallel sequencing technologies increases, NIJ's investments into research projects that support sequence analysis-based methods to identify body fluids are becoming more relevant to potential practice.

accurately differentiate one body fluid from another may be increased, meaning that presumptive or preliminary identifications can be moved toward more confirmatory conclusions. Also, the time and effort required to complete testing could be decreased and sample consumption and destruction could be minimized. Currently, all commonly used testing methods involve exhausting a portion of the evidence sample to test for each body fluid presumed to be present. NIJ continues to support and fund innovative research to address the need for new tools to better identify body fluids while minimizing the consumption of evidence. (See sidebar, "Body Fluid Identification.")

Empowering Criminal Justice Stakeholders and Victims Through Forensic Science

Forensic evidence as collected and analyzed is unbiased, as the science does not judge. Science is about revealing facts. For example, finding a fingerprint at the scene of a crime does not imply guilt or innocence; it is offered only to identify that a person was at a particular location or touched a particular item at some point, not whether he or she committed a crime. Any inferences drawn depend on the criminal justice practitioner using the information. Solving

Body Fluid Identification (continued)

Scientific methods used to identify body fluids, as currently performed or as they may be in the future, are important factors that can influence the crime scene investigation, inform the forensic laboratory processing, and affect court outcomes. Regardless of the perceived adequacy of existing methods, it is critical to continue to advance the field, building on new scientific findings and technologies that continue to evolve rapidly. As the field moves forward, it is critical to also continue to generate publicly available scientific knowledge that rigorously tests new methods, validates that the methods can do what they purport, and ultimately supports the foundation for the new tools and technologies that are adopted into practice.

Notes

1. Ewelina Mistek and Igor K. Lednev, "Identification of Species' Blood by Attenuated Total Reflection (ATR) Fourier Transform Infrared (FT-IR) Spectroscopy," *Analytical and Bioanalytical Chemistry* 407 no. 24 (September 2015): 7435-7442.
2. Claire K. Muro, Kyle C. Doty, Luciana de Souza Fernandes, and Igor K. Lednev, "Forensic Body Fluid Identification and Differentiation by Raman Spectroscopy," *Forensic Chemistry* 1 (August 2016): 31-38; Kyle C. Doty, Claire K. Muro, Justin Bueno, Lenka Halamkova, and Igor K. Lednev, "What Can Raman Spectroscopy Do for Criminalistics?" *Journal of Raman Spectroscopy* 47 no. 1 (January 2016): 39-50; and Gregory McLaughlin and Igor K. Lednev, "In Situ Identification of Semen Stains on Common Substrates via Raman Spectroscopy," *Journal of Forensic Sciences* 60 no. 3 (May 2015): 595-604.
3. Jennifer Fore et al., "Recent Progress in the Development of a Surface-Enhanced Raman Spectroscopy (SERS) Platform for Rapid Identification of Trace Amounts of Human Body Fluids," proceedings of the 68th Annual Scientific Meeting of the American Academy of Forensic Sciences, B184, 2016; and Kathryn Anne Zegarelli et al., "Surface-Enhanced Raman Spectroscopy (SERS) for the Forensic Analysis of Vaginal Fluid," proceedings of the 68th Annual Scientific Meeting of the American Academy of Forensic Sciences, E39, 2016.
4. Heyi Yang et al., "Proteomic Analysis of Menstrual Blood," *Molecular and Cellular Proteomics* 11 no. 10 (October 2012): 1024-1035; Heyi Yang et al., "Body Fluid Identification by Mass Spectrometry," *International Journal of Legal Medicine* 127 no. 6 (November 2013): 1065-1077; and Kevin M. Legg et al., "Discovery of Highly Specific Protein Markers for the Identification of Biological Stains," *Electrophoresis* 35 no. 21-22 (November 2014): 3069-3078.

sexual assault crimes — bringing rapists to justice and supporting victims — is much more complicated than simply testing SAKs.

All aspects of criminal justice practice — from the initial investigation through adjudication — can benefit from DNA and non-DNA forensic evidence. However, processing and analyzing forensic evidence in a timely and efficient manner are critical. Delays in testing make the use of forensic evidence impractical during the investigative phase; therefore, many law enforcement officers do not realize the full potential of all forensic evidence as a tool for developing new leads in investigations.²⁷ For example, NIJ's *National Best Practices for Sexual Assault Kits: A*

Multidisciplinary Approach emphasizes the importance of the identification, collection, and preservation of all evidence, not just DNA, from victims and crime scenes. The forensic science community has a responsibility to provide investigators with the answers they need, when they need them. As technology and testing methods advance, new tools may become available, throughput will increase, and the benefits of forensic analysis on various types of evidence may be better realized earlier in investigations.

Within this complex process, the forensic evidence itself affects many of the decision points, including but not limited to decisions to arrest, referral for and filing of charges, plea arrangements, and court

outcomes. The justice system has come to rely a great deal on various types of evidence to help link a suspect to a crime scene and to the victim, but often in sexual assault cases, forensic evidence is also used to corroborate or refute statements of fact. That is, the findings from forensic testing are also used to substantiate a victim's or suspect's account. In rape cases where a DNA profile from a suspect is recovered, the findings may affirm the victim's testimony and even empower the victim, because their story is now corroborated.²⁸

It is critical to provide increased training for law enforcement, prosecutors, and judges on the application and scientific validity of forensic evidence. In addition, increasing the capacity of our nation's laboratories to process *all* forensic evidence and advancing policies and best practices for the collection and processing of evidence are crucial to the timely and accurate testing and delivery of results to the law enforcement and judicial communities. Furthermore, the criminal justice system needs sound research that not only advances current forensic practice but also substantiates the existing validity of forensic evidence analyses, so all involved can be assured that the evidence being proffered against someone is sound. Evidence has a voice; we must ensure that science continues to be just and unbiased and that those who are listening are trained and accountable.

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For More Information

Read NIJ's "National Best Practices for Sexual Assault Kits: A Multidisciplinary Approach" at nij.ojp.gov, keyword: safer.

Read about the NIJ-FBI sexual assault kit partnership at nij.ojp.gov, keyword: nij-fbi.

To learn more about rape and sexual assault, go to nij.ojp.gov, keyword: rape.

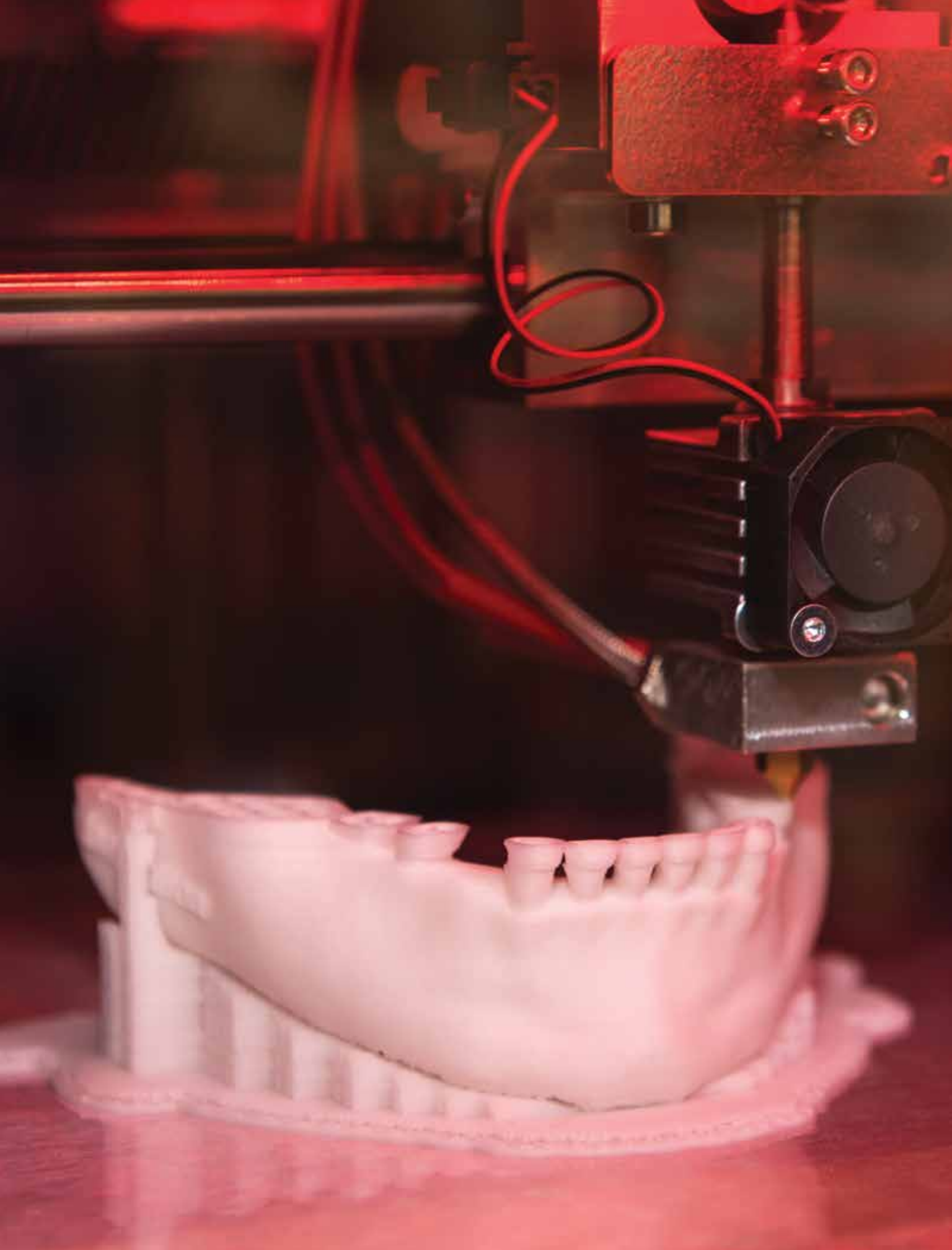
Read about sexual assault on campus at nij.ojp.gov, keyword: campus assault.

Read four brochures to help address issues with unsubmitted sexual assault kits in your jurisdiction at nij.ojp.gov, keyword: Ilkits.

Notes

1. "Many attorneys, judges, and journalists have claimed that watching television programs like CSI has caused jurors to wrongfully acquit guilty defendants when no scientific evidence has been presented. The mass media quickly picked up on these complaints. This so-called effect was promptly dubbed the 'CSI effect,' laying much of the blame on the popular television series and its progeny." Donald E. Shelton, "The 'CSI Effect': Does It Really Exist?" *NIJ Journal* 259 (March 2008): 1-7, NCJ 221500, <https://www.nij.gov/journals/259/pages/csi-effect.aspx>.
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3. Michael Briody, "The Effects of DNA Evidence on Sexual Offence Cases in Court," *Current Issues of Criminal Justice* 14 (2002): 159.
4. Joseph Peterson et al., "Sexual Assault Kit Backlog Study," Final report to the National Institute of Justice, grant number 2006-DN-BX-0094, June 2012, NCJ 238500, <https://www.ncjrs.gov/pdffiles1/nij/grants/238500.pdf>.
5. This should not preclude investigators from obtaining a DNA sample from the suspect to upload into the FBI's Combined DNA Index System (CODIS) database, which may help to establish whether the suspect has a history

- of “acquaintance rapes” or has committed other unsolved crimes.
6. As of January 2017, CODIS requires 20 core loci for DNA data to be included in the DNA database. Federal Bureau of Investigation, “Frequently Asked Questions on CODIS and NDIS,” February 17, 2017, <https://www.fbi.gov/services/laboratory/biometric-analysis/codis/codis-and-ndis-fact-sheet>. Basic criteria for a CODIS entry are as follows: documentation that a crime was committed, a documented request to collect consensual partners/elimination samples, the evidence produced a DNA profile that was foreign to the victim, and the DNA profile meets the FBI’s data quality requirements.
 7. An assailant’s DNA profile may be probative in a sexual assault case where consent is at issue, if the DNA profile links the perpetrator to other similar crimes.
 8. Studies represent unique projects with unique circumstances and should not be compared against one another; the results are an illustration of consistency that less than 50 percent of SAKs produce CODIS-eligible profiles.
 9. Cases reviewed within NIJ’s Cold Case program are not limited to sexual assaults.
 10. Seth Augenstein, “South Dakota Clears Rape Kit Backlog – 16 Percent CODIS Hits,” *Forensic Magazine* (January 23, 2017).
 11. Noelle Phillips, “Colorado Eliminates Backlog of Rape Test Kits, Identifies Suspects in Hundreds of Old Cases,” *The Denver Post*, July 16, 2016, <http://www.denverpost.com/2016/07/16/rape-kit-backlog/>.
 12. T. Christian Miller and Ken Armstrong, “An Unbelievable Story of Rape,” New York: ProPublica and The Marshall Project, 2015, <https://www.propublica.org/article/false-rape-accusations-an-unbelievable-story>.
 13. Joseph L. Peterson, Steven Mihajlovic, and Michael Gilliland, *Forensic Evidence and the Police: The Effects of Scientific Evidence on Criminal Investigations*, Washington, DC: U.S. Government Printing Office, 1984; cited in Donald Johnson et al., “Use of Forensic Science in Investigating Crimes of Sexual Violence: Contrasting Its Theoretical Potential With Empirical Realities,” *Violence Against Women* 18 no. 2 (2012): 193-222, <http://journals.sagepub.com/doi/pdf/10.1177/1077801212440157>.
 14. Michael Planty et al., *Female Victims of Sexual Violence, 1994-2010*, Special Report, Washington, DC: U.S. Department of Justice, Bureau of Justice Statistics, March 2013, NCJ 240655, <https://www.bjs.gov/content/pub/pdf/fvsv9410.pdf>.
 15. Specific charges would be dependent on state laws.
 16. Tasha A. Menaker, Bradley A. Campbell, and William Wells, “The Use of Forensic Evidence in Sexual Assault Investigations: Perceptions of Sex Crimes Investigators,” *Violence Against Women* 23 no. 4 (2017): 399-425.
 17. Ibid.
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THE NEXT GENERATION OF CRIME TOOLS AND CHALLENGES: 3D PRINTING

BY RUBY J CHASE AND GERALD LAPORTE

3D printing technology both supports and challenges criminal investigation.

Although it is relatively new from the perspective of its appearance in criminal investigations, 3D printing technology — or additive manufacturing — is not new. It originated in the 1980s;¹ only in the past decade have 3D printers become smaller and affordable enough for the mass market. (You can purchase a basic 3D printer, which fits on a desk, for well under \$1,000.) Today, this technology is widely available and relatively simple to use for both lawful and illicit purposes.

3D printers can create a variety of highly customizable objects at relatively low cost. Their applications are nearly endless. Examples of the commercial application of 3D printing include, but are not limited to, manufacturing airplane and automotive parts, footwear, and medical and veterinary prosthetics.

3D printing technology has also been used for criminal justice purposes. Crime scene investigators and forensic examiners have used it in accident reconstruction, replication of crime scene evidence, and facial reconstruction from unidentified skeletal remains.

Criminals are also taking advantage of the versatility of this technology. Among the most worrying of its illicit uses is the creation of 3D-printed guns and other weapons.²

The technology is widely available and relatively simple to use, and criminals will undoubtedly find more creative ways to use it. As a consequence, we expect to see 3D printers and their products submitted for forensic analysis in criminal investigations, if they have not already been. Forensic examination of 3D printers and their products is challenging. Because of the newness of this technology from an evidentiary perspective, there is a lack of both forensic research and validated test procedures. This limits the ability of forensic scientists to offer definitive conclusions regarding this technology or its products.

Understanding the Technology

Traditional manufacturing processes subtract materials — for example, drilling out part of the object to create holes or grinding down a steel ball bearing to achieve the desired shape. Additive manufacturing

3D printing technology is relatively simple to use and can help support criminal investigations. But it is also a tool for criminals, who can use the technology to print guns and other weapons and objects for a host of nefarious activities.

refers to the process of creating an object by adding materials, a process that all 3D printers use.

There are three general steps to creating an object by 3D printing:

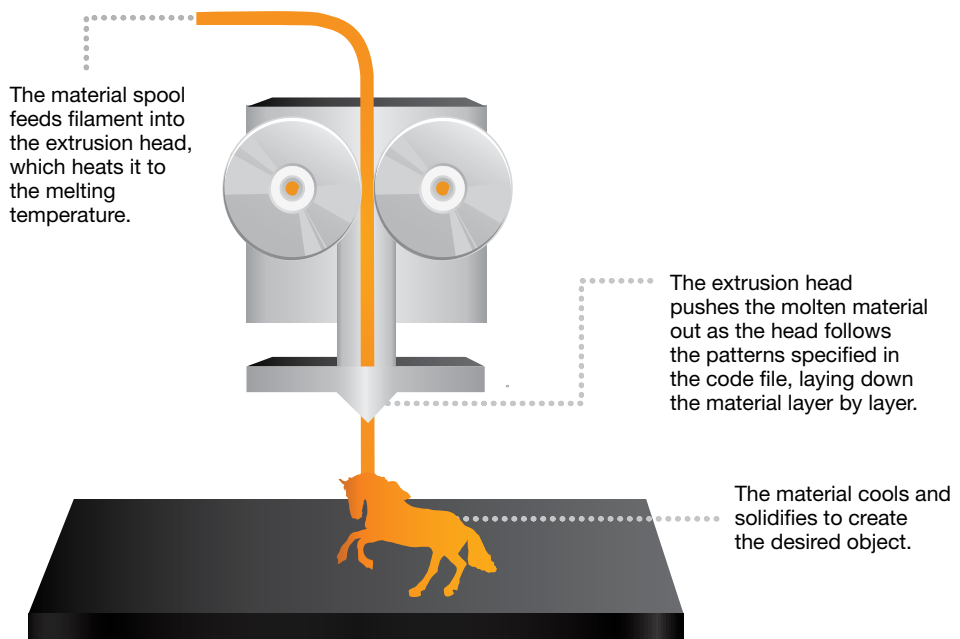
- Create a 3D model (a blueprint) of the object to be printed, using computer-aided design (CAD) software.

- Translate the model into very thin two-dimensional, cross-sectional layers (slices) of the object.
- Print the object by depositing layers of a material, or materials, in two-dimensional slices until the object is fully formed in 3D.

The process of printing an object with a 3D printer can begin in one of four ways. The most difficult is creating the model of an object “from scratch” using CAD software. Less difficult is developing the model using a 3D scan or digital images of an object — taken from multiple aspects — as a starting point. The easiest way to begin the process is by using an existing model. Models of a variety of different objects are readily available from several open-source file-sharing sites.

3D-printed objects are created by depositing one layer of printing material at a time in a pattern that follows the model specifications until the object is complete. This can be done using a variety of materials, the most common of which are thermoplastic polymers, photopolymers, resins, ceramics, and metals. Printing

Exhibit 1. Printing Process of Fusion Deposition Modeling



could take minutes, hours, or days, depending on the complexity and size of the model and the material used.³

There are a number of different 3D printing processes. They vary in how the printing material is deposited and bonded together, based on the properties of the materials used. The most common process used for desktop 3D printers is material extrusion, or fusion deposition modeling (FDM). These printers use inexpensive thermoplastic filament as the printing material.⁴ As shown in exhibit 1, the process is simple: Spooled thermoplastic filament is fed to a heated extrusion head, where it is heated to a high temperature and forced out of the heated nozzle as the print head moves. The material bonds and hardens as it cools. Exhibit 2 shows an example of a horse printed from an FDM printer.

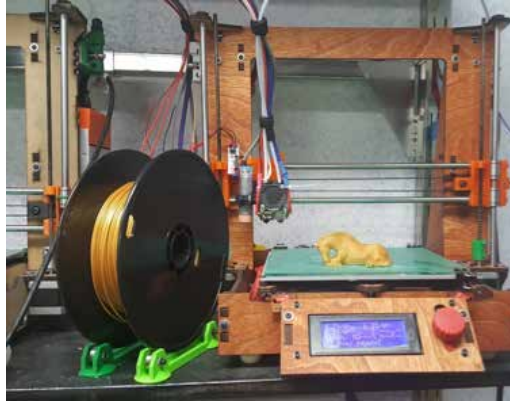
Forensic Applications of 3D Printing

Criminal justice practitioners can use the technology to print replicas of evidence and crime scenes for easier courtroom demonstrations and for a more efficient facial reconstruction process. (See sidebar, “NIJ Projects Involving 3D Printing.”)

Creating replicas of evidence is not a new practice; dental stone casts of footprints and Mikrosil casts of toolmark impressions are commonplace.⁵ However, casting is not always practical in cases where the substrate — such as soil — quickly deteriorates or is prone to deformation. In these cases, time is a factor; 3D printing offers a solution to this challenge. Crime scene technicians can capture photographs of the impression from many different angles and then use photogrammetry software to create an accurate surface model of the impression. Using the images, they can print an exact replica — or as many as they need — as opposed to the traditional method of casting the impression directly to obtain a reverse image of the evidence.

In its first use of 3D printing, the Devon and Cornwall Police in Exeter, England, enlisted Plymouth City College to design a replica of a weapon — a broken Newcastle Brown Ale bottle — that was used to fatally

Exhibit 2. An FDM-Printed Object



Note: Many of the parts of the FDM printer have been printed by an already completed 3D printer.

Source: Photo taken by Ruby J Chase, on behalf of NIJ.

stab Alex Peguero Sosa in the neck. The suspect, Lee Dent, testified that it was self-defense and that he did not realize he was holding the bottle when he hit Sosa. However, after demonstrating to the court how he held the bottle using a 3D replica of the broken bottle, it was clear to the jury that he was aware of the deadly weapon in his hand. After eight hours of deliberation, Dent was convicted of murder in 2015 for his brutal attack.⁶

3D printing technologies helped police understand one particularly gruesome case in Birmingham, England, and present printed body parts to the jury instead of disturbing and distracting graphic photos.⁷ Convicted killer Lorenzo Simon murdered Michael Spalding in 2014, then dismembered the body, stuffed most of it into two suitcases after trying unsuccessfully to burn some of the bones, and threw the suitcases into a local canal.⁸ Police recovered part of the victim's humerus from an oil drum furnace found in Simon's garden and the two suitcases filled with Spalding's body parts from the canal. Nine pieces of bone from the oil drum and the suitcases were x-rayed at different angles using 3D scanning technology that displayed the cuts on the bone in minute detail. 3D printing experts at the University of Warwick made replicas of the bones to demonstrate the evidence to the jury, showing that one of the oil drum bones was a

NIJ Projects Involving 3D Printing

NIJ is already funding projects that use 3D printing for forensic applications. For example, the University of New Mexico sought to optimize magnetic resonance imaging (MRI) acquisition settings, receiver coil sensitivities, and subject positioning for infants, toddlers, and children. This was necessary because MRI coils are typically designed to scan parts or regions of adult subjects. The university printed 3D MRI phantoms — designed to evaluate and optimize system performance for different tissue types or physical geometries — of pediatric head, neck, and shoulders models to assess and optimize the performance of available coils. The first set of photos shows 3D MRI phantoms of a 3-month-old, a 6-month-old, and a 12-month-old child for comparison and a phantom of the 3-month-old in a small flex coil ready for the MRI.

In another project, the University of Central Florida used 3D printing to prototype and produce a portable fluorometer for drug detection in the field (see second set of photos to the right). The spectrometer can interface with a cell phone and identify substances from a cloud-based database. 3D printing is precise enough to produce the optical paths needed for the spectrometer to function, while also resulting in a lightweight device. The use of 3D printing allowed for a rapid and inexpensive redesign of the prototype and enabled production of the spectrometer at a cost to the consumer of less than \$50.



Source: Photos courtesy of the University of New Mexico.



Source: Photos courtesy of the University of Central Florida.

seamless fit with a limb found in one of the suitcases. The printed bones were used in court demonstrations, and Lorenzo Simon was convicted. (See exhibit 3 for an example of how printed bones can be used in court.)

Small items of evidence can also be printed at a large scale to show detail. Impression evidence such as

friction ridge impressions (latent prints), footwear, and tire treads captured using 3D technology can be enlarged to examine specific details that may not be visible to the naked eye and can be used for courtroom demonstrations. For example, using large-scale models of two compared fingerprints that display shared minutiae may help the jury understand the evidence's significance and limitations.

Exhibit 3. Humerus and Femur Prints with an FDM Printer



Note: Bones like these can be used in court to show how two pieces fit together instead of showing graphic photos.

Source: Photos taken by Ruby J Chase, on behalf of NIJ.

3D printing is also becoming useful in facial reconstruction. In traditional facial reconstruction, artists layer clay on to a real skull until facial features are restored and then take pictures of the restored face.⁹ However, this practice can damage the skull. It is also standard practice to have several artists create reconstructions to focus on facial features that are difficult to discern solely from the shape of the skull.¹⁰ The entire process gets completed several times on the same skull, one artist at a time, with the potential for skull damage increasing with each reconstruction. 3D printing and other software systems can eliminate the need to handle the original skull beyond scanning it once (see exhibit 4). Several artists can receive the computer model of the skull and create virtual reconstructions using software programs that imitate clay reconstruction, or they can receive 3D-printed replicas for traditional reconstructions.¹¹ Because each artist would have his or her own skull replica, the clay does not have to be stripped and the entire set of reconstructions can be saved and compared.

Exhibit 4. 3D-Printed Skull



Note: Printed skulls like this one can be used for facial reconstructions to minimize damage to the real skull.

Source: Photo taken by Ruby J Chase, on behalf of NIJ.

The use of 3D printing for investigations and court demonstrations is still new, but the possibilities and potential applications in this area will continue to evolve.

Illicit Applications of 3D Printing

The primary concern from a criminal justice perspective with regard to 3D printing is the ability to manufacture difficult-to-detect, untraceable contraband.

The 3D printing community has an open-source mindset, and so users have access to several repository websites from which they can download a design file instead of creating their own. Of course, the industrial community and even some hobbyists prefer to patent and restrict access to their designs, but the criminal justice field is less concerned with those files. The open-source files, however, are of great concern because anyone can download and

modify them. They can download and use design files and blueprints for weapons or bomb parts, regardless of their intent. An innocent object could be modified for illicit applications. The download and modification of these files is not currently federally regulated, but the State Department has proposed regulation of posted blueprints for 3D-printed firearms.¹² Also, the most popular open-source repository's terms of service state that by using the site, you agree not to collect, upload, transmit, display, or distribute any content that promotes illegal activities or contributes to the creation of weapons.¹³

Using 3D printing technology to create guns is a controversial topic; despite the controversy, there is no doubt that building a gun with a 3D printer can be done with relative ease using inexpensive technology. There is very little regulation on making and owning a 3D-printed gun, which, in turn, creates challenges in identifying parts and materials during an investigation. Users have already shown that anyone with a low-end 3D printer can download publicly available, open-source files and print the plastic parts to make a working firearm. The threat of homemade, untraceable firearms is real — a murder-suicide in 2016 in Walnut Creek, California, and a 2013 mass murder at a Santa Monica college were both committed with homemade weapons, colloquially termed “ghost guns” because they are not made with serial numbers. California recently passed a law, effective on July 1, 2018, that will require a person who manufactures or assembles a firearm (including 3D-printed guns and other homemade firearms) to first apply to the California Department of Justice for a unique serial number or other identifying mark.¹⁴

In addition to creating difficult-to-detect, untraceable contraband like firearms or bomb parts, criminals are using 3D printing for other illicit purposes, such as to manufacture counterfeit parts that can be used in fraud cases. In fall 2014, Spanish and Bulgarian authorities infiltrated an organized crime ring that was committing credit card fraud by printing the equipment to manufacture fake plastic card slot bezels installed on ATMs and point-of-sale terminals as “ATM skimmers.” The criminal network was operating in Italy, France, Spain, and Germany;

authorities made 31 arrests and confiscated more than 1,000 devices.¹⁵

New printer technologies debut regularly. Printing materials such as carbon fiber, titanium, and other metals are becoming more popular, and printers capable of printing in metal are becoming less expensive.¹⁶ The law enforcement community is concerned about people printing metal objects such as explosive devices, weapons, or other parts for illicit purposes. In addition, criminals who enter the country illegally and need to acquire weapons or other equipment for illegal activity can use 3D printers — this may be difficult for law enforcement to trace.

3D printing may also offer a way to successfully bypass a number of biometric security measures. Materials like thermoplastic polyurethane and nylon remain flexible when printed and could be used to print a fingerprint or a handprint. This includes friction ridge detail and blood vessels underneath the “skin,” so warm blood substitute can make the fake print warm, as if it is living tissue. It is also feasible that a desktop printer could print the pattern of blood vessels in the eye to bypass retinal scanning. The applications for which criminals could use 3D printing are limited only by their creativity.

Forensic Investigation of Crimes Involving 3D Printing

Investigations involving 3D printing are likely to include collection and analysis of digital media, such as CAD files, and physical evidence such as printed objects, printers, and printing materials. Computer forensics can play a pivotal role during the investigation of crimes involving 3D printers; however, here the focus is on the analysis of physical evidence.

The objective of most forensic examinations involving physical evidence is either to analyze an item to determine its origin or to compare the item with materials seized from a known source to determine if they share an origin. The analysis of most physical evidence includes identifying class characteristics that may be common to a manufacturer or a specific model, and individual characteristics that are unique

markings imparted on an item from a specific 3D printer.

Forensic scientists can use visual, microscopic, optical, and trace-chemical methods to analyze and compare physical evidence related to 3D printers; these same methods are commonly used to link questioned documents with inkjet printing devices.¹⁷ Although forensic analyses are available to analyze metals, plastics, resins, polymers, and a host of other trace materials, there is very little research on the analysis of 3D-printed objects to evaluate individual characteristics imparted from the printer. For example, tracking a printed object back to an individual printer or a spool of thermoplastic filament (or other printing material) would be extremely helpful during an investigation. There are also other trace-chemical examinations to consider, such as analyzing finishing products (e.g., paints or dyes) that may have been used, or pollens and dust caught in the printed object as the printing material dried.

There is great potential to recover latent prints and DNA from 3D printers (and their components) and printed objects. Understanding the type of surface of a 3D-printed object is critical to recovering a quality latent print; forensic scientists can use different chemical methods to recover prints, depending on the surface type. Given that 3D-printed objects may have different pliability, porosity, or other physical variations, we need more research to optimize latent print recovery. Finally, DNA analysis can be a powerful forensic method for linking a suspect to an object, but once again, more work is necessary to understand and optimize recovery of DNA evidence from the various materials available for 3D printing.

A Need for More Research

Over the years, 3D printing technology has become inexpensive and easy to use, allowing the public to have access to this advanced manufacturing process. The criminal justice system is using 3D printing in evidence replication, facial reconstruction, crime scene reconstruction, and court demonstrations. While 3D printing is a tool that can support investigations, it is also a tool for criminals, who can use the

technology to print guns and other weapons and objects for a host of nefarious activities.

A completed FDM object does not require post-treatment unless the hobbyist uses support material in the printing. With the FDM technique, one cannot deposit printing material without somewhere to deposit it, so some objects require support material to be printed underneath overhanging parts of the object.¹⁸ Users will need to remove the support material to obtain the final, desired object. Users can also sand, polish, and paint the object, although the objects are difficult to finish in this way because

Exhibit 5. 3D Printing Striations



Note: This close-up shows the striations present in all 3D-printed objects.

Source: Photo taken by Ruby J Chase, on behalf of NIJ.

of the striations that the layers produce as they are deposited (see exhibit 5). Each change made to a printed object introduces individualities that can be analyzed, but how the object changes with each type of post-treatment has not been studied.

The thermoplastic filament used for FDM printers includes, but is not limited to, ABS (acrylonitrile butadiene styrene), PLA (polylactic acid), PVA (polyvinyl acid), PC (polycarbonate), TPU (thermoplastic polyurethane), nylon, and PETG (polyethylene terephthalate), which is a version of PET modified specifically for 3D printing.¹⁹ Forensic scientists can conduct trace-chemical examinations on all of these thermoplastics, but there is very little research on the forensic value of this type of analysis and on whether forensic scientists could make conclusive statements about the origins of a 3D-printed object.

Forensic capabilities are currently lagging because there has been limited exposure to crimes involving 3D printers. There is also little research on how to associate the materials and objects with a specific 3D printer or class of printers. For example, materials such as PETG, copper-infused filament, and wood-fiber-infused filament are being designed specifically for FDM 3D printers; research could help identify and forensically compare these materials. 3D printers and the objects they print, as well as the associated software and files, are likely to have evidentiary value with a greater understanding of this technology.

About the Authors

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For More Information

To learn more about NIJ's forensic science portfolio, go to NIJ.ojp.gov, keyword: forensic science.

This article discusses the following grants:

- "Investigation of Post-Mortem Magnetic Resonance Imaging for the Detection of Intraneural Hemorrhage," grant number 2013-DN-BX-K004
- "Transition Metal Cluster Compounds for the Fluorescent Identification and Trace Detection of Substances of Abuse," grant number 2012-R2-CX-K005
- "Low-Cost Handheld Spectrometer and Cloud-Based Data Analysis for Improved Identification of Substances of Abuse," grant number 2015-R2-CX-0035

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LOST BUT NOT FORGOTTEN: FINDING THE NATION'S MISSING

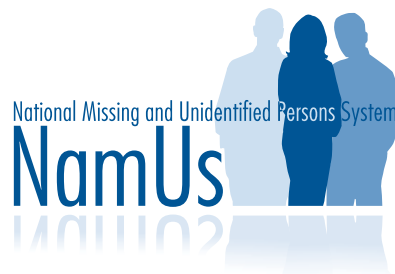
BY DANIELLE WEISS, DAWN SCHWARTING, CHARLES HEURICH, AND HEATHER WALTKE

As NamUs nears its 10th anniversary, we reflect on the program's history, successes, and continued commitment to helping families. The NamUs program provides police officers, medical examiners and coroners, and other criminal justice professionals with the investigative and scientific tools needed to find missing persons, identify decedents and victims of crime, resolve criminal cases, and reduce violent crime and human trafficking. In addition to the NamUs program, other NIJ-funded missing persons programs from across the country have made great strides in resolving cases and bringing the lost home.

When a loved one goes missing, every day that passes is a painful reminder of that person's absence. Finding the lost is not an easy task, but it is a critical responsibility we have to families.

In March 1994, Maryland police found the body of a deceased male with extensive injuries to his face. No identification could be made at the time. For 14 years, he remained a John Doe and his family had no idea what had happened to him. It would take a community coming together to identify him.

In March 2008, the Maryland Center for Missing and Unidentified Persons (Maryland Center) helped the state medical examiner's office upload its unidentified persons cases to NIJ's National Missing and Unidentified Persons System (NamUs), a repository and resource center for the nation's missing and



unidentified persons. A request was made to have a forensic artist create an image of the man's face using old photographs found in the original missing persons file. In September 2008, an improved image of the man's likeness was added to the NamUs case profile. A local newspaper ran a story about the case and included the new image. Within two weeks, a woman contacted the Maryland Center saying she believed the man in the story was David Riddick, her missing 23-year-old nephew. Further investigation confirmed

NamUs is a cornerstone to ensuring that criminal justice agencies have the tools they need to help families, further investigations, and solve some of the most complex cases.

David's identity. His family learned that he had been shot to death while walking home from a missing person's vigil in Baltimore City. After 14 years, David was finally returned home.

Carla Proudfoot, director of the Maryland Center, said, "NamUs was instrumental in getting this case solved and bringing some resolution to the man's aunt." She added that the case highlighted the importance of communication and collaboration between criminal justice agencies, especially those in neighboring jurisdictions, and engaging with families and the general public to help resolve these heartbreaking cases.¹

NamUs is a cornerstone to ensuring that state and local criminal justice agencies have the tools they need to help families and further investigations. Housed in NIJ's Office of Investigative and Forensic Sciences, NamUs is a web-based system provided free of charge to medical examiners, coroners, law

enforcement officials, allied forensic professionals, families with lost loved ones, the general public, and anyone else who is trying to resolve these cases. NamUs is a permission-based system, meaning it offers both a publicly viewable area and a restricted criminal justice-sensitive environment, ensuring the protection of privileged information. With diverse users in all 50 states and all U.S. territories, NamUs is a collaborative system that bridges the communication gap among stakeholders, fostering enhanced information sharing and investigative case support.

As the program approaches its 10-year anniversary, the U.S. Department of Justice and NIJ remain committed to their mission to provide leadership, resources, and solutions for creating safe, just, and engaged communities, and to create partnerships with other public and private agencies and organizations. As such, NIJ continues to upgrade and expand the NamUs system and its offerings to better meet the needs of criminal justice agencies and searching families and to help solve some of the most complex cases.

A Brief Look Back

In 2007, NIJ reported on the "Nation's Silent Mass Disaster," describing the more than 100,000 active missing persons cases and more than 40,000 sets of unidentified human remains in the United States.² At the time, resources to assist with unidentified remains

Still Searching

NamUs is a forum for families, across generations, to know that their loved one has not been forgotten. The oldest case in NamUs is a gentleman named Elijah Cravens, who has been missing since 1902. Cravens was last known to be riding a horse to the Woodsman of the World Fair in Oklahoma. He was never heard from again. Although he may not be found, he will always have a resting place in NamUs, where he will be remembered.

Another cold case dates back to 1920. Marvin Clark disappeared in Oregon after boarding a stagecoach on his way to a doctor's appointment. His family continues to seek answers. Based on family reference samples, NamUs recently performed mitochondrial DNA analysis on an unidentified person also found in Oregon. Although the mitochondrial DNA did not match, Clark's family knows that NamUs will continue to search.

and missing persons were minimal and disjointed, and something needed to be done.

NIJ hosted the Identifying the Missing Summit in 2005, during which the missing persons community voiced a need for improved access to missing persons information. They identified two principal needs. The first was a centralized repository for the nation's unidentified and a way to capture essential information, including biometrics that would allow for comparisons with open missing persons cases. The second was a way to close the communication gap between agencies, jurisdictions, and the public so they could share information, collaborate on cases when needed, and help relatives in their search for family members.

To help meet these needs, NIJ created two programs to aid the country in reporting, locating, and identifying missing persons. The first program was NamUs. The second — Using DNA Technology to Identify the Missing — complements NamUs services by helping

medical examiners, coroners, law enforcement agencies, and allied professionals collect and analyze DNA samples; employ other critical identification methods such as fingerprints, dental records, and anthropology; and foster relationships and build bridges within the community to gather more robust data on the nation's lost.

By the end of 2007, the NamUs unidentified decedents database was online, followed by the missing persons database. NIJ continued to expand the system and added another complementary database for unclaimed persons, which includes deceased people who have been identified but for whom no next of kin has been located to claim them.

As of February 2017, NamUs contains records for 12,833 missing persons, 11,335 unidentified persons, and 2,582 unclaimed persons (see exhibits 1 and 2); and the number of cold cases³ continues to grow.

Exhibit 1. Active NamUs Missing Persons (MP) Cases by State

The graphic below illustrates the number of MP cases published in NamUs, by state, as of February 1, 2017.

Total MP Cases = 12,832

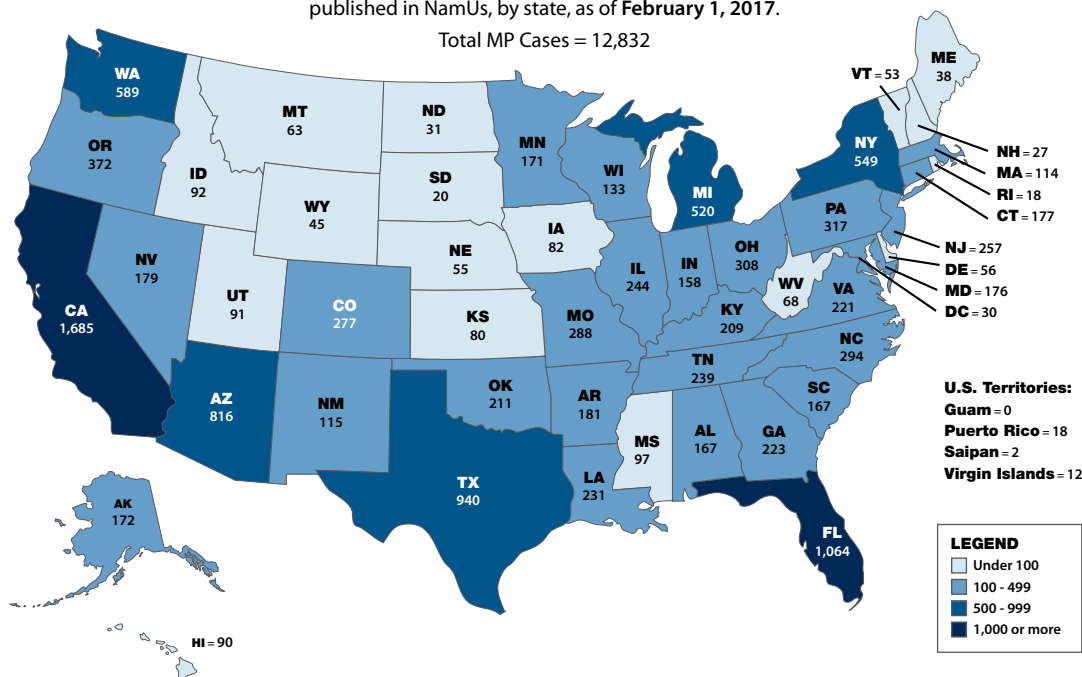
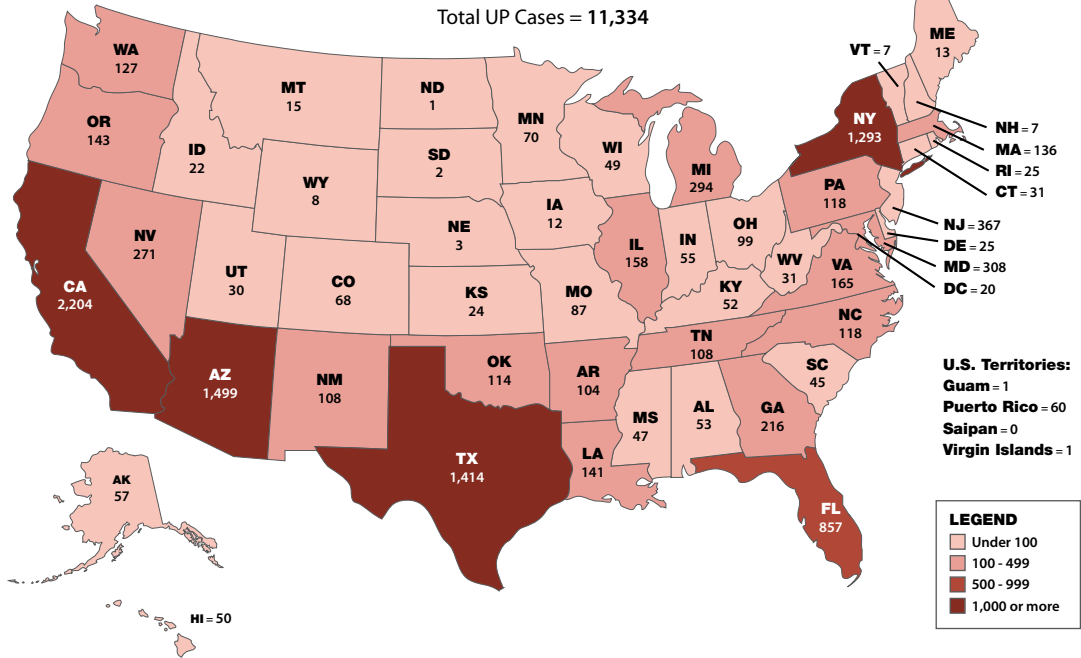


Exhibit 2. Active NamUs Unidentified Persons (UP) Cases by State

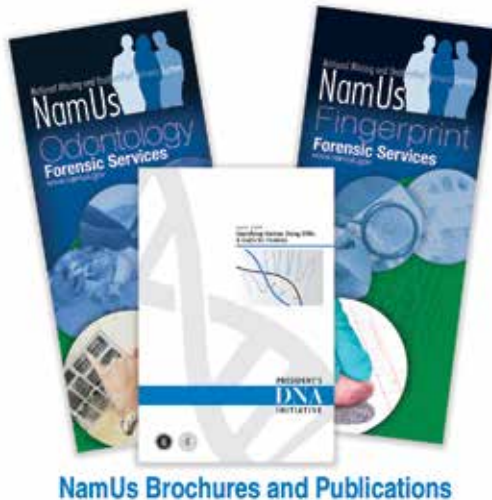
The graphic below illustrates the number of UP cases published in NamUs, by state, as of February 1, 2017.



Technical Assistance and Forensic Services

Although the crux of NamUs is its centralized database system, the program has evolved over time into a network of services that are currently managed by the University of North Texas Center for Human

Identification in collaboration with NIJ. Eight regional system administrators (RSAs) throughout the country help bridge the gap between family members, law enforcement, medical examiners and coroners, and NamUs services. RSAs provide training and direct technical assistance to stakeholders and families. Cold cases are the most challenging and complex cases to solve — every unidentified person has someone searching for answers, and many of these cases lead to an unresolved death investigation. RSAs provide critical support and technical assistance to law enforcement and medical examiners nationwide — services in need of expansion as thousands of new missing and unidentified persons cases arise each year. (See sidebar, “Still Searching.”)



Funding from NamUs⁴ and the Using DNA Technology to Identify the Missing program⁵ provides community and professional stakeholders with numerous benefits, including family reference sample kits; DNA testing of unidentified remains; and other forensic services, such as fingerprint, anthropology, and odontology

Finding Loved Ones Alive

NamUs has had numerous resolutions over the years and has reunited lost loved ones with their families. Sometimes the missing person is located alive and safe. For example, NamUs reunited a man from Uganda with his family, who had lost contact with him. In another case, a man who went missing from Colorado was located in Florida six years later.

Whether a person is lost, voluntarily missing, or abducted, the case is an open investigation for law enforcement. Law enforcement officials have credited NamUs with their ability to close cases and help conserve limited resources. Unfortunately, not all cases have a happy ending, but NamUs can still support medical examiners, coroners, law enforcement, and families by facilitating information sharing and providing a search forum.

assistance, provided free of charge to any jurisdiction in the country. NamUs also has a toll-free phone number⁶ available to assist people who lack access to the internet, have questions, or need translation services. The missing persons and unidentified persons databases and NamUs resources are also available in Spanish.⁷

What NamUs Data Show

In addition to the many services NamUs provides to criminal justice agencies, the system can also offer invaluable insights into the nation's lost. For instance, of the 12,950 active missing persons cases in NamUs as of February 2017, 5,440 (42 percent) involve missing females and 7,510 (58 percent) involve missing males. Of those, the average age of missing females and males is 30 years and 36 years, respectively, with an overall average age of 33 years for all active missing persons.

Resolution of long-term cold cases can sometimes be complicated by factors such as where someone was last seen, where they were thought to have been, and communication failures between agencies across jurisdictional boundaries. However, many missing persons cases are resolved quickly. According to the Federal Bureau of Investigation's National Crime Information Center, 661,000 missing persons cases were reported in 2012, but only 2,079 were still active at the end of the year.⁸

Many reported missing persons are found alive. Of the 12,621 missing persons cases in NamUs that have been resolved, 9,584 (76 percent) were located alive, and 3,037 (24 percent) were found to be deceased. Of the missing persons who were recovered alive, 5,189 (54 percent) were female and 4,393 (46 percent) were male. The mean age for all missing persons found alive is 26 years, with a mean age of 22 years for missing females found alive and 30 years for missing males found alive. However, what all of these individuals have in common is that someone was searching for them. (See sidebar, "Finding Loved Ones Alive.")

Many of the unidentified human remains that are entered into NamUs are not readily identifiable. Of the 11,335 active unidentified persons cases in NamUs, only 2,745 (24 percent) were noted to have recognizable faces. Factors that prevent visual recognition of the decedent include, but are not limited to, burning/charring, insect predation, traumatic injury, decomposition, and skeletonization of the body due to environmental factors (see exhibits 3 and 4).

A gender disparity was noted for the unidentified persons in NamUs — of the 2,988 missing persons who were found deceased, 960 (32 percent) involved missing women and 2,028 (68 percent) involved missing men. Additional research is needed to discern the cause of this disparity.

Exhibit 3. Resolved NamUs Unidentified Persons Cases by Identification Method		
Identification Method	Number of Cases	Percentage of Cases
DNA (mtDNA and/or nucDNA)	1,437	45.63
Fingerprint	610	19.37
Circumstantial	283	8.99
Dental	245	7.78
Anthropology	216	6.86
Visual	216	6.86
No ID method provided to NamUs	96	3.05
Body radiographs	46	1.46

Exhibit 4. Active NamUs Unidentified Persons Cases by Condition of Body		
Recognizable Remains	Number of Cases	Percentage of Cases
Recognizable face	2,745	24.88
Unrecognizable Remains	Number of Cases	Percentage of Cases
Charred/burned	323	3.90
Decomposition	2,491	30.06
Insect activity	51	0.62
Mummification	293	3.54
Near or complete skeleton	1,308	15.78
Partial remains with soft tissue	510	6.15
Partial skeletal remains	3,033	36.60
Traumatic injuries	278	3.35
Total Unrecognizable Cases	8,287	
Unknown Recognition	Number of Cases	Percentage of Cases
Null body condition field	303	2.67
Total Cases	11,335	

Applying Evolving Technology to Solve Cases

As noted above, when unidentified remains are recovered, a visual identification is often not possible given the state of the remains; however, many forensic technologies and tools can help investigators. NIJ's Office of Investigative and Forensic Sciences has a robust research and development portfolio that supports the enhancement and creation of tools and techniques to identify, collect, analyze, interpret, and preserve evidence. For example, DNA analysis techniques can produce a profile from minute and degraded samples. Mitochondrial DNA (inherited through maternal genes) and Y-STR (inherited through paternal genes) are two common DNA analysis methods that can provide useful information when looking for familial relationships. NIJ grantees such as the New York City Office of Chief Medical Examiner⁹ and the University of North Texas Center for Human Identification¹⁰ assist criminal justice agencies around the country by using techniques to extract DNA from bone samples and apply specialized anthropological expertise to degraded skeletal remains.

New and developing technologies allow scientists to offer medical examiners more leads into what a person might have looked like. Phenotypic DNA analysis is an evolving process that examines information from a DNA profile to predict physical features of the sample's contributor. For example, NIJ funded Yale University researchers in their development of high-resolution single nucleotide polymorphisms — variations in one's DNA — for forensic identification of ancestry, family, and phenotype from DNA samples. Also, the University of Tennessee began evaluating a forensic chip assay and phenotypic analysis system to assess the utility and accuracy to predict phenotypic characteristics from skeletal remains.

Through NIJ's Using DNA Technology to Identify the Missing program, agencies are able to bring new technologies to the field and integrate innovative techniques. For example, the New York City Office of Chief Medical Examiner purchased a 3D printer that enables it to recreate the skulls of unidentified

persons. Forensic artists can then complete facial reconstructions without harming the original skull. The University of South Florida's¹¹ Institute of Forensic Anthropology and Applied Sciences provides a similar service and coordinates events such as the Art of Forensics program, a mass media event to display facial reconstructions completed at the institute to help identify the nameless.

Other forensic technologies being used include facial and clothing imaging. Facial imaging is similar to 3D facial reconstruction except that the skull is scanned into a computer system and computer programs then create the image. This same technique can be used on other items of evidence, such as clothing and artifacts found with the person. Radiographic analysis is also used to examine the bodies and note any old or new injuries or abnormalities.

Several agencies are also using stable isotope analysis to help determine the possible region in which an unidentified person recently lived. For example, isotopes, which are different forms of the same chemical element, vary in water and in specific foods that people eat. The variation in isotope ratios found in human remains can help scientists and investigators assess a person's recent geographical residence or travel history. New York City, commonly referred to as the melting pot of the world, has used isotopic analysis on at least 88 cases. NIJ also offers funding for pollen analysis, which has been proposed for use in the forensic analysis of unidentified persons cases to help place a person in a specific region.

Program Successes

NIJ grantees have used federal funding in many ways, from testing individual cases within their state to undertaking large-scale projects. For example, the New York City Office of Chief Medical Examiner completed 39 exhumations for the Potter's Field Identification Project¹² to help resolve more than 200 missing persons cases and identify the approximately 1,200 unidentified persons buried in the city's Potter's Field graveyard since the late 1980s. Additionally, the University of South Florida's Institute of Forensic Anthropology and Applied Sciences exhumed 51 sets

Missing Persons Days

Several NIJ awardees support missing persons days, events in which the host agency encourages people who have a missing family member or friend to gather at a specified location. These events often include educational sessions to learn about missing persons resources; collection of DNA family reference samples; collection of personal and descriptive information, records, and photos of the missing loved one; and collection of the missing person's personal items that might still be a viable source for their DNA, such as a toothbrush.



NamUs does not house DNA profiles; samples are analyzed and profiles are uploaded into the Combined DNA Index System. Known DNA samples and data are essential for missing persons databases to be successful in making identifications, and missing persons days have been effective in obtaining case and forensic information. For example, the New York City Office of Chief Medical Examiner solved nine missing persons cases through its 2015 missing persons day. In one case, a woman attended the missing persons day in hopes of finding her 63-year-old sister. Her family reference sample provided the information needed to identify a woman who had died after being hit by a train in 2007.

of human remains from the grounds of the Dozier School for Boys, which was under state investigation to examine the suspicious circumstances of children who died or went missing while in custody.¹³

One important factor contributing to the thousands of unidentified remains found in the United States is the increase in foreign nationals migrating to this country and those who fall victim to human trafficking, especially along the southern border states of Texas, Arizona, and California. Many of the human remains recovered in this region have limited or no records available to assist with an identification. Through NIJ programs, the Conference of Western Attorneys General (CWAG)¹⁴ has been working with the Mexican states of Baja California, Chihuahua, Coahuila, Guanajuato, and Sonora to obtain family reference samples — DNA samples collected from family members of the missing for forensic identification. The CWAG project is the first international collaborative effort of its type. Collaboration is critical to help resolve these cases across borders. To that end, CWAG has also assisted with cases of U.S. citizens who may have died while in Mexico. With the use of NIJ funding, CWAG facilitated the identification of a



Through NIJ programs, the Conference of Western Attorneys General is working to solve missing persons cases that cross borders.

U.S. citizen found in Rosarito, Mexico, and was able to provide some resolution to the family and return their loved one to the United States. The project also obtained a Combined DNA Index System (CODIS) match that connected a set of remains to a family in Guanajuato, Mexico, and 13 CODIS matches to unidentified remains submitted by the Pima County (Arizona) Office of the Medical Examiner.

Families Helping in the Search

NamUs is the only “cemetery” many families can visit until their loved one is found. In 2016, an unidentified male was found deceased in the Arizona desert. The local medical examiner’s office entered the decedent’s information into NamUs, including information about a tattoo. At the same time, the young man’s family had been regularly searching NamUs. Once the medical examiner entered the man into the system, the family almost immediately identified their loved one by some of his unique features. Not only was the case resolved, but the family did not have to feel helpless. Families can be involved in the process.

But More Can Still Be Done

The Bureau of Justice Statistics’ Census of Medical Examiner and Coroner Offices, released in 2004,¹⁵ found that about 4,400 unidentified human decedents are reported in an average year, 1,000 of whom remain unidentified after one year. Cold case investigators require more resources and access to innovative techniques to tackle growing caseloads; however, state, local, and tribal resources continue to be scarce and agency priorities limit the investigative assets that can be dedicated to these cases. As cases persist, NIJ programs provide invaluable resources to stakeholders across the country to help find missing persons and identify human remains, ensuring that new as well as cold cases can be investigated, innovative tools and techniques can be employed, and no one is forgotten.

Law enforcement, medical examiners and coroners, forensic laboratories, and families and loved ones of the missing and unidentified need access to additional support services. Exhumation assistance, victim advocacy support, and proactive forensic sample collection, for example, would enhance support and better assist agencies and families. A proactive measure, such as biometric collection kits (e.g., fingerprints, DNA swabs, and dental records), could be offered to families for personal retention, which would provide valuable identification information in the unfortunate event that a person goes missing. Future outreach activities could focus on vulnerable and at-risk populations, as well as on families with

children who are traveling or leaving home to attend college. Additional facial reconstruction services would present a greater opportunity for public identification of remains that are no longer recognizable.

Forensic DNA testing, facial reconstruction, and isotope and phenotype analysis are all very expensive, but law enforcement needs access to these state-of-the-art techniques if they hope to resolve these cases, strengthen public safety, and help reduce crime. These forensic services — when coupled with missing persons days (see sidebar, “Missing Persons Days”), DNA family reference sample collections, dental and fingerprint examinations, and other outreach service campaigns — will hopefully lead to more case resolutions.

How do resource shortfalls affect a searching family? In one recent case, it took two years to exhume an unidentified female to collect a DNA sample due to funding and resource shortages. Although a lead was identified after 25 years of searching, the family had to wait two additional years for funding to become available to make the identification. More can and should be done.

Currently, Congress does not mandate the use of NamUs, so it is up to states and the community of stakeholders to drive this voluntary system forward, as the system is only as strong as the cases that it contains. After 10 years, stakeholder successes have encouraged states to embrace the use of NamUs. Currently, five states have passed state laws that

include the use of NamUs. Although it still does not mandate the use of NamUs by law, California has been an active user and advocate of the system since inception, passing legislation that removed a barrier to sharing law enforcement information with the NamUs system and including NamUs in its training guidelines.¹⁶ Connecticut, New York, and Tennessee passed legislation mandating that all medical examiners enter decedent information into NamUs.¹⁷ The professional community is also embracing the value of NamUs: the National Association of Medical Examiners has included a NamUs link on its webpage, and the International Association of Coroners and Medical Examiners has included the use of NamUs in its accreditation checklist requirements.

NamUs 2.0

NamUs is currently undergoing a technology enterprise upgrade to enhance the suite of services that can be offered to state and local communities. In addition to an enhanced user experience and search capabilities, NIJ is focusing on a gap identified during its strategic planning: a subpopulation in need. Mass-casualty, large-scale, and multistate incidents — often called “critical incidents” — present unique challenges when it comes to finding missing persons and reuniting families. The attacks on September 11, the Boston Marathon bombings, hurricanes and tornadoes, disease outbreaks, and transportation disasters are just a few of the tragic incidents that have occurred on a massive scale and at a very high human cost.¹⁸ As part of the NamUs upgrade, a new component is being developed to help agencies deal with the issues of victim accounting, identification, and reunification during critical-incident events. NamUs has taken up the call to help law enforcement, medical examiners, coroners, emergency responders, and the public account for and hopefully reunite families during these chaotic events.

Join the Search

Missing and unidentified persons cases have public safety and public health implications. The identification of a person is the first step in any investigation, and

any corresponding evidence uncovered could lead to resolution or justice for those lost. Many of these cases are the result of criminal activity or occurred under suspicious circumstances; therefore, identifying those who remain nameless will directly assist in safeguarding the country as a whole.

Ten years after its inception, NamUs remains committed to finding those reported missing and identifying those who are found but unknown. The program coordinates with state and local law enforcement agencies and medical examiners and coroners agencies to increase the quality of data, strengthen investigative services, and foster communication. NamUs continues to identify and provide needed resources to underserved and underfunded stakeholders who have significant roles and responsibilities in supporting these federal, state, local, and tribal criminal justice communities. The system directly affects criminal investigations and the resolution of missing persons and unidentified remains cases through technical assistance and forensic and analytic services, and it provides a forum for the public to provide leads and help in the search for loved ones (see sidebar, “Families Helping in the Search”). NamUs increases the quality of case data and the timeliness of information sharing that is so critically needed to inform criminal justice and public safety partners.

The U.S. Department of Justice is committed to helping the lost find their way home to their families, supporting law enforcement agencies in their search for the missing, and helping the medical examiners and coroners who are the final voice for the dead. To join the search or for more information, please visit NamUs.gov — where the lost will never be forgotten.

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For More Information

Learn more about NamUs at NamUs.gov.

Read more about NIJ funding to help identify missing persons at NIJ.ojp.gov, keyword: missing persons funding.

Notes

1. Beth Pearsall and Danielle Weiss, "Solving Missing Persons Cases," *NIJ Journal* 264, November 2009, <https://www.nij.gov/journals/264/Pages/solving.aspx>.
2. Nancy Ritter, "Missing Persons and Unidentified Remains: The Nation's Silent Mass Disaster," *NIJ Journal* 256, January 2007, <https://www.nij.gov/journals/256/Pages/missing-persons.aspx>.
3. All numbers in this article are current as of February 2017. For the purposes of this article, cold cases are cases for which all significant investigative leads have been exhausted.
4. National Institute of Justice funding opportunity, "National Missing and Unidentified Persons System (NamUs)," grants.gov announcement number NIJ-2016-9079, posted March 4, 2016, <https://NIJ.gov/funding/Documents/solicitations/NIJ-2016-9079.pdf>.
5. National Institute of Justice funding opportunity, "Using DNA Technology to Identify the Missing," grants.gov announcement number NIJ-2015-4055, posted February 12, 2015, <https://www.ncjrs.gov/pdffiles1/nij/SL001154.pdf>.
6. The toll-free phone number for NamUs is 1-855-626-7600.
7. Visit the NamUs Spanish site at <https://www.findthemissing.org/es>.

8. Audie Cornish, interview with Todd Matthews, "Majority Of Missing Persons Cases Are Resolved," *All Things Considered*, NPR, May 7, 2013, <http://www.npr.org/2013/05/07/182000622/majority-of-missing-persons-cases-are-resolved>.
9. For more information on DNA services provided by the New York City Office of Chief Medical Examiner, see <http://www1.nyc.gov/site/ocme/index.page>.
10. For more information on the University of North Texas Center for Human Identification services, see <http://www.untchi.org/>.
11. For more information on the University of South Florida's missing persons services, such as the Art of Forensics program, see <http://www.forensics.usf.edu/>.
12. National Institute of Justice, "Using DNA Technology on Unidentified Individuals from New York City's Potter's Field," award to the New York City Office of Chief Medical Examiner, grant number 2009-DN-BX-K038.
13. For more information on the Dozier School for Boys project, see <http://news.usf.edu/article/templates/?a=7173&z=224>.
14. For more information on the Conference of Western Attorneys General's missing persons programs, see <https://www.cwagweb.org/project/fsic-missing-persons-resource-center/>.
15. Updated data will soon be available, as the Bureau of Justice Statistics intends to perform another census of medical examiners' and coroners' offices in 2018-2019.
16. S.B. 1066, Chapter 437 (Calif. 2014), https://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=201320140SB1066; and California Commission on Peace Officer Standards and Training, *Missing Persons Investigations: Guidelines & Curriculum*, Sec. 14201.3, Information Accessibility (December 2011), <http://lib.post.ca.gov/Publications/missing.pdf>.
17. Connecticut: S.H.B. 6113, Public Act No. 11-102 (Conn. 2011); New York: S.B. A10278A/S07987A (New York 2016); and Tennessee: H.B. 0044/S.B. 0113 (Tenn. 2017).
18. Since 2000, there have been approximately 161 mass fatality incidents and almost 9,000 deaths.

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UNCERTAINTY AHEAD: A SHIFT IN HOW FEDERAL SCIENTIFIC EXPERTS CAN TESTIFY

BY DANIELLE WEISS AND GERALD LAPORTE

A new directive instructs Department of Justice forensic scientists working in federal laboratories and United States Attorneys to refrain from using the phrase “reasonable degree of scientific certainty” when testifying. How will state and local forensic scientists and other attorneys alter their testimonial practice?

When scientific experts express their opinions (or conclusions) in court, they are often asked if their opinion is to a “reasonable degree of scientific certainty,” “reasonable degree of medical certainty,” or some variation of this terminology. This phrase has been used in courts throughout the nation for decades and signals that the expert’s testimony is based on sound scientific or technical analysis rather than conjecture.

Forensic scientists working in federal laboratories have been instructed to no longer use the phrase “reasonable degree of scientific certainty” in court testimony. On September 6, 2016, the Department of Justice’s Office of the Attorney General issued a memorandum¹ and directed forensic laboratories to review their policies and procedures to ensure that forensic examiners do not use “reasonable degree of scientific certainty” or “reasonable degree of [forensic discipline] certainty.” Department prosecutors were also asked to abstain from using these expressions when presenting forensic reports or questioning forensic experts in court unless required by a judge or applicable law.

Undoubtedly, the new policy to refrain from using the phrase “reasonable degree of scientific certainty” represents a significant change to the testimonial language that attorneys and scientific experts have routinely used. While the directive issued by the Attorney General was issued to federal laboratories and prosecutors, there is some question as to if or how state and local courts, attorneys, and nonfederal forensic science service providers’ experts will alter their testimonial practices. Two important questions have since emerged: (1) Why not use “reasonable degree of scientific certainty” in testimony and (2) How will courts proceed?²

Why Not Use “Reasonable Degree of Scientific Certainty”?

One of the first and most important concepts introduced to aspiring scientists is the scientific method. This method can vary because not all questions can be answered using controlled experiments, but it has some basic tenets:³

1. Posing a question or hypothesis based on the appropriate background facts, knowledge, and information.

The History of “Reasonable Degree of Certainty”

According to a document issued by the National Commission on Forensic Science (NCFS),¹ “reasonable degree of certainty” was first used — not legally mandated — in *Herbst v. Levy* in 1935, when the plaintiffs’ expert, Fred Ludolph, testified about the circumstances of a capsized boat. Ludolph was “then given a hypothetical question containing some of the facts in evidence relating to the speed of the boat, the number of passengers, the condition of the water, and other circumstances, and asked whether he could determine with reasonable scientific certainty the cause of the capsizing of the boat.”²

It was not until 1969 that the terminology was linked to the admissibility determination. In *Twin City Plaza, Inc. v. Central Sur.* (1969), the court wrote:

If the witness, based upon his background skill, possesses extraordinary training to aid laymen in determining facts and if he bases his answer upon what he believes to be *reasonable scientific or engineering certainty*, generally the evidence should be admitted, subject, of course, to the cross-examination of the adversary. The weaker the scientific opinion or the less qualified the expert, the more vigorous will be the cross-examining attack and undoubtedly the less persuasive will be the opinion to the trier of fact.³ [emphasis added with italics]

According to NCFS, this statement was made without legal or scientific analysis as to what the term meant or why its use was being mandated.

Notes

1. Views of the Commission Regarding Use of the Term “Reasonable Scientific Certainty,” National Institute of Standards and Technology, at <https://www.justice.gov/archives/ncfs/page/file/831786/download>.

2. *Herbst v. Levy*, 279 Ill. App. 353, 358 (Ill. App. Ct. 1935), at <https://casetext.com/case/herbst-v-levy>.

3. *Twin City Plaza, Inc. v. Central Sur.* INS, 409 F.2d 1195, 1203 (8th Cir. 1969).

2. Collecting and analyzing information.
3. Evaluating and synthesizing that information.
4. Reaching a final conclusion.

During their education and training, scientists are neither taught nor required to state that the conclusion they reach in the final step is to a “reasonable degree of scientific certainty” (see sidebar, “The History of ‘Reasonable Degree of Certainty’”).

Although the scientific community has not defined this phrase or any of its variations, it has been

offered in an attempt to demonstrate that the expert’s conclusion is not based on mere speculation, but rather scientific principles, education, training, experience, or specialized knowledge. Even though the phrase is commonly used, it has no definition from a scientific perspective outside of the courtroom. It is not a standard applied to scholarly publications or peer review, nor is it taught, defined, or generally accepted in scientific practice. Consequently, one could argue that if the terminology is not generally used in scientific practice, then scientists should not be expected to express their conclusions to a

“reasonable degree of certainty.” Additionally, the Federal Rules of Evidence 702-705 do not require its use,⁴ and while very few states require an obligatory recitation of this phrase contemporaneous with the admission of an expert’s testimonial conclusions, many states still ask for the recitation.

Does this phrase really bolster a jury’s assessment of forensic evidence? No scientific study has determined whether an expert who uses a statement like “reasonable degree of scientific certainty” either misleads fact-finders or changes the actual meaning of the testimony. Scientific testimony can be quite extensive and complex, possibly taking several hours or even days to explain results and conclusions. Without having evidence through comprehensive research, it is impossible to truly assess the impact of using “reasonable degree of scientific certainty.” But it is incumbent upon scientists to always communicate their findings accurately, especially in a courtroom setting when they are testifying to nonscientists and where certain words or phrases may be misunderstood or misconstrued. In that setting, there is a valid concern that inexact terminology could be misunderstood or taken out of context by the jury. As such, technical terms of art, including those used in the expert’s conclusions, should be defined — in reports and during testimonial presentations — particularly when a layperson could reasonably understand the expert’s conclusions to imply certainty.

In a recent NIJ-sponsored study, Nicholas Schweitzer of Arizona State University conducted three experiments involving jury simulations and mock trials to assess how jurors respond to certain types of forensic testimony (see sidebar, “Study of Juror Judgments”).⁵ Schweitzer concluded that a forensic science expert’s experience and display of confidence while testifying were the most powerful factors that caused jurors to perceive his or her testimony as credible. The intangible aspects of a testimonial presentation (expert’s credentials, influence, and confidence) seem to substantiate an expert’s conclusions. Interestingly, civil fact-finders were more likely to find a defendant liable when testimonial evidence was presented than when records and data alone were placed into evidence. Even when the jury

was already aware of the underlying information, the evidence became more persuasive when offered through expert testimony.⁶ Accordingly, it may be the case that, rather than being overwhelmed by the impact of scientific evidence, jurors are more influenced by a combination of factors, including the expert’s demeanor, his or her background and experience, and the overall persuasiveness of the testimonial presentation. Taking all of these factors into account, it is imperative that the jury not also be influenced by words implying certainty when that level of assurance cannot be substantiated, regardless of the discipline.

Additionally, the phrase has never received a cross-disciplinary definition and continues to evoke differing interpretations. For example, Black’s Law Dictionary defines “reasonable degree of ‘medical’ certainty” as “a standard requiring a showing that the injury was more likely than not caused by a particular stimulus, based on the general consensus of recognized medical thought.”⁷ However, some have argued that when used by expert witnesses in criminal cases, the term “reasonable scientific certainty” conveys a stronger degree of probability or level of certainty and may be interpreted by jurors as equivalent to the government’s burden of proving all the elements of a crime beyond a reasonable doubt.⁸ And while neither the courts nor published research cites a definition with such a high standard, researchers Dawn McQuiston-Surrett and Michael J. Saks note that “forensic expert witnesses cannot simply adopt a term, define for themselves what they wish it to mean, and expect judges and juries to understand what they meant by it.”⁹ Nevertheless, the intent for using the phrase has meaning and purpose to courts and legal practitioners, which is to summarily demonstrate that the expert’s opinion rises above the level of speculation and conjecture. This leads us to the next logical question: How will courts proceed?

Moving Forward: Exploring Options on How to Proceed

One alternative is to discontinue using “reasonable degree of scientific certainty” and not replace this “summary” term with another. That is, let the

Study of Juror Judgments

by **Eric Martin** and **Angela Moore**

Forensic science can be a powerful tool, but there has been limited robust scientific inquiry into how jurors perceive and weigh forensic testimony. To fill this knowledge gap, Arizona State University researcher Nicholas Schweitzer conducted an NIJ-supported study examining the impact of forensic evidence testimony on juror decisions.¹ Schweitzer designed a study of jurors' reactions to forensic science using three criteria. First, he used juror-eligible participants. Second, Schweitzer videotaped a dramatization of a criminal case but altered three factors of interest: expertise of the forensic expert testifying, admonitions of the jury, and challenges of the forensic expert by the defense counsel. Trial practitioners verified the realism of the case transcripts to ensure that the variables of interest were studied in a realistic courtroom application and would mirror what actual jurors would have to consider. Finally, he focused on the use of non-DNA forensic science in the courtroom, specifically testimony on fingerprint and bite mark analysis.

After watching the video, the mock jury deliberated on the merits of the case. The deliberations were recorded to assess the impact of the forensic testimony on the jury. Also, each juror was given a survey before and after jury deliberations to capture their attitudes regarding forensic testimony and how these attitudes may have changed after deliberating with their colleagues. Schweitzer used the survey results to gauge the impact of the deliberation process on jurors' thoughts about forensic science and their decision-making.

Schweitzer conducted three experiments to study different aspects of forensic expert testimony. In the first experiment, he analyzed juror responses to determine if the forensic scientist's expertise and the validity of the forensic science discipline influenced juror decision-making. Schweitzer found that the forensic scientist's experience appeared to have more influence on the jurors than the scientific validation of the methods. The experience of the scientist, however, did not seem to affect the jury's verdict when the mock jury recommended a verdict to acquit or convict the defendant.

The second experiment examined the effect of the forensic expert's degree of certainty regarding the presence of exculpatory evidence on jurors' decision-making. Schweitzer found that the mock jurors initially were not swayed by the possibility of exculpatory evidence, but the influence of this potential evidence became greater through the deliberation process. In the post-deliberation survey, the presence of exculpatory evidence was as influential on jury decision-making as the forensic scientist's experience.

Finally, the third experiment investigated how jurors perceived the forensic expert's concession that the analysis may include errors. The results were mixed. When the trial involved bite mark analysis, the concession of potential errors decreased the value of the evidence. However, when the case included fingerprint analysis, the concession increased the perceived credibility of the analysis. Schweitzer concluded that this may be indicative of the jurors' own a priori attitudes toward the forensic method being used; fingerprint analysis may have had more credence among jurors prior to their participation in the mock trial.

These findings represent a first step in understanding how jurors perceive forensic testimony, how those initial perceptions change through deliberations, and how those perceptions are ultimately translated into verdicts. A potential limitation of the study is that it focused only on bite mark and fingerprint analysis. Future research should be conducted to try to replicate these findings with other forensic methods to understand how the type of method used may affect juror impressions of forensic testimony.

Note

1. Nicholas J. Schweitzer, "Communicating Forensic Science," Final report to the National Institute of Justice, grant number 2008-DN-BX-0003, May 2016, NCJ 249804, <https://www.ncjrs.gov/pdffiles1/nij/grants/249804.pdf>.

About the Authors

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conclusions and statements expressed by an expert stand on their own. But if there is an option to replace the term, how do we move forward?

Bridging the fields of science and law creates challenges for forensic scientists. The intended meaning of a particular word or phrase may not be what criminal justice stakeholders — investigators, lawyers, and fact-finders — understand it to mean.

Scientists regularly share theories, analyses, and conclusions with each other, and peers often challenge or reproduce their conclusions. Yet when they share the same information externally with nonscientists, intended meanings can get lost in translation or the information may be misconstrued. For example, forensic scientists have used phrases like "consistent with" or "similar to" to qualitatively conclude that two items cannot be differentiated based on the examinations performed. When these terms are used without any further explanation and qualification, a layperson may interpret these phrases to mean that the items being compared share a common source, which may not, in fact, be how the expert intended to convey their findings since they

are qualifying terms. These phrases are not intended to convey the forensic examiner's belief that the two items examined are identical in every respect. In those instances, the examiner will typically assert that he or she has "identified" a questioned item as originating from a known source.

An expert's clear and complete explanation of his or her findings, including the limitations of the method employed, is critical to a juror's accurate understanding of an expert's scientific conclusions. Scientists and laypersons involved in the criminal justice system share common language, but they speak with very different dialects. A linguistic bridge needs to be identified and implemented that will enable scientists to accurately communicate their opinions and conclusions to interested parties while neither overstating nor understating their significance and intended meaning. The desire to build a linguistic bridge may have originally led to the use of phrases like "reasonable degree of scientific certainty" as a way for the legal and scientific communities to express to the fact-finder in a more concise manner the degree of confidence that an expert held in his or her opinions and conclusions.¹⁰ There is no indication

that the phrase was intended to confuse or obfuscate scientific findings. Instead, it seems that its purpose was to convey the expert's degree of confidence in his or her conclusions and to clarify that they are not based upon mere speculation.

One misconception about the field of forensic science is that it consists of a single discipline. In reality, forensic science comprises various scientific disciplines that use a diverse range of applied methods and techniques to help answer questions of legal significance. So there is an immense challenge to develop and define an appropriate phrase that can be used by all scientific disciplines. The National Institute of Standards and Technology's Organization of Scientific Area Committees, which has the primary responsibility to coordinate development of a quality infrastructure for forensic science standards, has established 23 subcommittees representing various forensic disciplines that range from computer forensics to DNA to forensic pathology. Hence, it will be quite a daunting task to identify a single phrase that all forensic disciplines can use to accurately distinguish between speculation and the relative degree of confidence that a scientist has in his or her findings and opinions. One likely approach will be that each discipline develops and defines its own terminology — through a formalized standards development process, during which the unique aspects of each discipline and the needs of those who will use this information will be taken into account.

Research has shown that jurors struggle with complex testimony and statistical information, which puts them at risk for misinterpreting evidence or dismissing information that they do not understand.¹¹ Some research has provided insight into the impact that scientific testimony can have on juror decision-making. However, this information is currently limited. Generally, the available research has shown that confident testimony by an experienced forensic expert has a positive influence on juries. Conversely, the use of highly technical methods, validation studies, cross-examination, exculpatory evidence,¹² concessions of error, explanations of the limitations of a methodology, and jury instructions had little overall impact on juror decision-making in the research setting.¹³ The

research appears to reinforce the hypothesis that the perceived experience¹⁴ and capabilities of a forensic expert may, in fact, outweigh the probative value of the evidence. However, in some cases, the scenarios offered to a mock jury in a research setting do not reflect, in totality, the overall deliberative process of a real trial.

In any case, jurors are noticeably influenced by confirmatory statements and an expert's ability to explicitly connect evidence to aspects or issues in a case. It is clear that the language used by forensic experts while testifying can have a substantial impact on a fact-finder's comprehension of the subject matter and decision-making.¹⁵ However, additional research is still needed to determine whether a direct correlation exists between specific words or phrases and the decisions made by jurors. Further research is also needed to determine which factors may directly affect how jurors react to and interpret the information provided by expert witnesses. Case type, factual context, jury composition, evidentiary complexities, and legal issues all play a role in the process of evaluating the evidence and deliberating on a verdict.

Moreover, the nature and design of studies will affect how mock jurors will evaluate the variables to which they are exposed. For example, will test subjects be exposed solely to mock testimony, or will they also be provided with instructions to guide their deliberations? Will test subjects be exposed to expert testimony in isolation, or will they participate with other mock jurors in a more realistic deliberative process? When studying how jurors evaluate expert testimony, it is critical not only to understand and control the variables that form component parts of the experimental hypothesis but also to understand the broader factors at play that may affect a juror's perception of the entire trial process.

Conclusion

There is no evidence to show that abstaining from the use of the phrase "reasonable degree of scientific certainty" will affect the inferences that jurors might draw from an expert's testimony or whether its omission will influence the outcome of a trial.

However, we do know that jurors will continue to make decisions that will be based, in part, on expert testimony. Accordingly, we must bridge the linguistic divide that separates scientists and laypersons. Informed by studies of juror comprehension, scientists must continue to develop and define terminology that accurately conveys both their opinions and the limitations of their methodology, cognizant of the risk that nonscientists may misunderstand their intended meaning. Each discipline in the forensic science community must standardize and define its terminology — with the comprehension of stakeholders and fact-finders in mind — and eliminate vague and ambiguous words and phrases. This will be the challenge for nonfederal forensic science service providers and lawyers — will they effectively eliminate the use of “reasonable degree of scientific certainty” and, if so, is an alternative necessary?

In the meantime, “reasonable degree of scientific certainty” continues to be a phrase that is still taught in some law schools and used in state and local courts on a daily basis. It is incumbent upon testifying scientists to identify and define appropriate terminology to help bridge the communication gap while enhancing juror comprehension of statements that convey scientific conclusions. In the absence of a clear alternative phrase, many legal professionals may be apprehensive about its disuse. However, the ultimate responsibility remains with the testifying expert to clearly explain his or her opinions and conclusions within the limitations of science and with words and phrases whose meaning is clearly understood by all.

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For More Information

Learn more about forensic science at NIJ at nij.ojp.gov, keyword: forensic science.

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- “Jurors’ Judgments About Forensic Identification Evidence,” grant number 2008-DN-BX-0003

Notes

1. U.S. Department of Justice, Office of the Attorney General, *Memorandum for Heads of Department Components* (Recommendations of the National Commission on Forensic Science), September 6, 2016, <https://www.justice.gov/opa/file/891366/download>.
2. Although expert witness testimony related to medicine, engineering, and a host of other non-forensic-science disciplines is regularly presented in courts, the focus of this discussion is on the forensic sciences.
3. See “Principles of Scientific Inquiry,” at <http://onlinepubs.trb.org/onlinepubs/nchrp/cd-22/manual/v1chapter2.pdf>.
4. See Federal Rules of Evidence (2015), at <http://federalevidence.com/rules-of-evidence>.
5. Nicholas J. Schweitzer, “Communicating Forensic Science,” Final report to the National Institute of Justice, grant number 2008-DN-BX-0003, May 2016, NCJ 249804, <https://www.ncjrs.gov/pdffiles1/nij/grants/249804.pdf>.
6. *Ibid.*
7. “Reasonable Medical Probability,” *Black’s Law Dictionary* (10th ed.) (Westlaw, 2014).
8. See *Views of the Commission Regarding Use of the Term “Reasonable Scientific Certainty,”* National Institute of Standards and Technology, at <https://www.justice.gov/archives/ncfs/page/file/831786/download>.
9. Dawn McQuiston-Surrett and Michael J. Saks, “Communicating Opinion Evidence in the Forensic Identification Sciences: Accuracy and Impact,” *Hastings Law Journal* 1159 (2007-2008): 59.
10. Loene M. Howes, “The Communication of Forensic Science in the Criminal Justice System: A Review of Theory and Proposed Directions for Research,” *Science and Justice* 55 (2015): 145-154.

11. Some research has shown that, in some cases, judges are more capable than jurors at understanding complex testimony.
12. Exculpatory evidence seemed to be more influential on jurors during the deliberation phase of the trial. See Schweitzer, "Communicating Forensic Science."
13. Dawn McQuiston-Surrett and Michael J. Saks, "The Testimony of Forensic Identification Science: What Expert Witnesses Say and What Fact Finders Hear," *Law and Human Behavior* 33 (2009): 436-453; Joseph Eastwood and Jiana Caldwell, "Educating Jurors about Forensic Evidence: Using an Expert Witness and Judicial Instructions to Mitigate the Impact of Invalid Forensic Science Testimony," *Journal of Forensic Science* 60 no. 6 (2015): 1523-1528; and McQuiston-Surrett and Saks, "Communicating Opinion Evidence."
14. Jurors seem to think that credibility is akin to being an expert "who is a good teacher, with sound credentials and acceptable motives," in Sanja Kutnjak Ivkovic and Valerie P. Hans, "Jurors' Evaluations of Expert Testimony: Judging the Messenger and the Message" (Cornell Law Faculty Publications, 2003): 385, <http://scholarship.law.cornell.edu/facpub/385>.
15. McQuiston-Surrett and Saks, "The Testimony of Forensic Identification Science"; and McQuiston-Surrett and Saks, "Communicating Opinion Evidence."

NCJ 250699

JUST WRONG:

The Aftermath of Wrongful Convictions

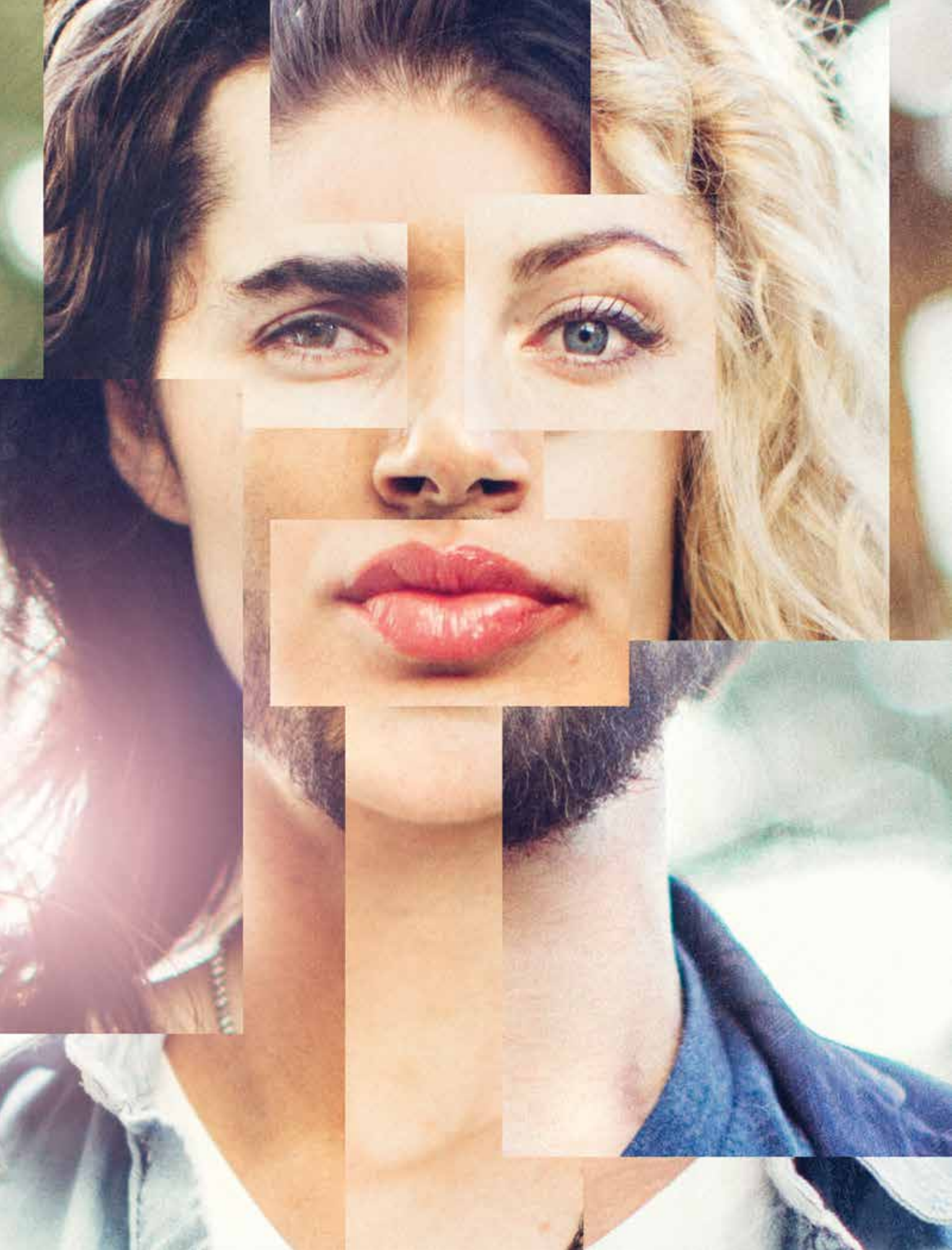
The strength of our criminal justice system depends on its ability to convict the guilty and clear the innocent. But we know that innocent people are sometimes wrongfully convicted and the guilty remain free to victimize others. The consequences of a wrongful conviction are far-reaching for the wrongfully convicted and the survivors and victims of the original crimes.

NIJ, along with its partners in the Office of Justice Programs and external organizations, hosted listening sessions with victims and survivors of crimes that resulted in wrongful convictions and with individuals who have been exonerated. NIJ recently released a documentary that revisits several participants of these listening sessions to provide them with a forum to explain how wrongful conviction changed their lives and how they are coping with the consequences today.

The documentary, “Just Wrong: The Aftermath of Wrongful Convictions, From Crime Victims to Exonerees,” chronicles the experiences of three exonerees who spent decades in prison for crimes they did not commit and three crime victims or survivors whose lives were impacted by a wrongful conviction.



**To see and hear their stories, watch
“Just Wrong” at [NIJ.ojp.gov](https://www.nij.ojp.gov),
keyword: just wrong.**



THE IMPORTANCE OF DIVERSITY AND INCLUSION IN THE FORENSIC SCIENCES

BY IRIS R. WAGSTAFF AND GERALD LAPORTE

To strengthen the forensic sciences, we must engage people from a broad array of scientific disciplines and backgrounds to help provide innovative solutions to complex criminal justice issues.

The benefits of diversity within an organization are well documented.¹ Having people of different races, ethnicities, genders, socioeconomic status, and backgrounds within a workplace can drive innovation, problem-solving, and competitiveness. Research has shown that diverse teams perform better, are more creative, and outperform homogeneous teams.² Increasing diversity in thought, perspectives, and backgrounds allows for new and more complex research questions and problems to be addressed. Research has also documented a direct link between diversity and quality of scientific work as measured by peer review journal citations.³

As the forensic sciences continue to evolve, it is critical that we leverage the skills and expertise of people from all backgrounds to provide innovative solutions to complex issues. According to the Bureau of Labor Statistics, employment in the science and engineering sectors — which support the forensic sciences — grew by 10.5 percent (817,260 jobs) between May 2009 and May 2015,⁴ compared with 5.2 percent net growth in nonscience-related

occupations. This growth outpaces the production of talent currently being trained to fill these jobs. To strengthen the forensic sciences, it is imperative that we train and employ more forensic scientists and foster an environment in which uniqueness and difference are embraced and valued.⁵

To this end, NIJ is developing strategies and policies to solicit the participation of all segments of the population to fulfill its mission. NIJ is committed to casting a wide net that will allow us to engage the best and the brightest from a broad array of scientific disciplines and backgrounds to support rigorous and innovative research to solve criminal justice problems.

The Diversity of the Forensic Sciences

The word “forensic” comes from the Latin term *forensis*, which means “in open court, public, from the forum.”⁶ Forensic science is the application of scientific principles and methods to matters of law and comprises a broad array of science, math, and engineering disciplines, the largest being biology and chemistry. Most forensic scientists obtain a

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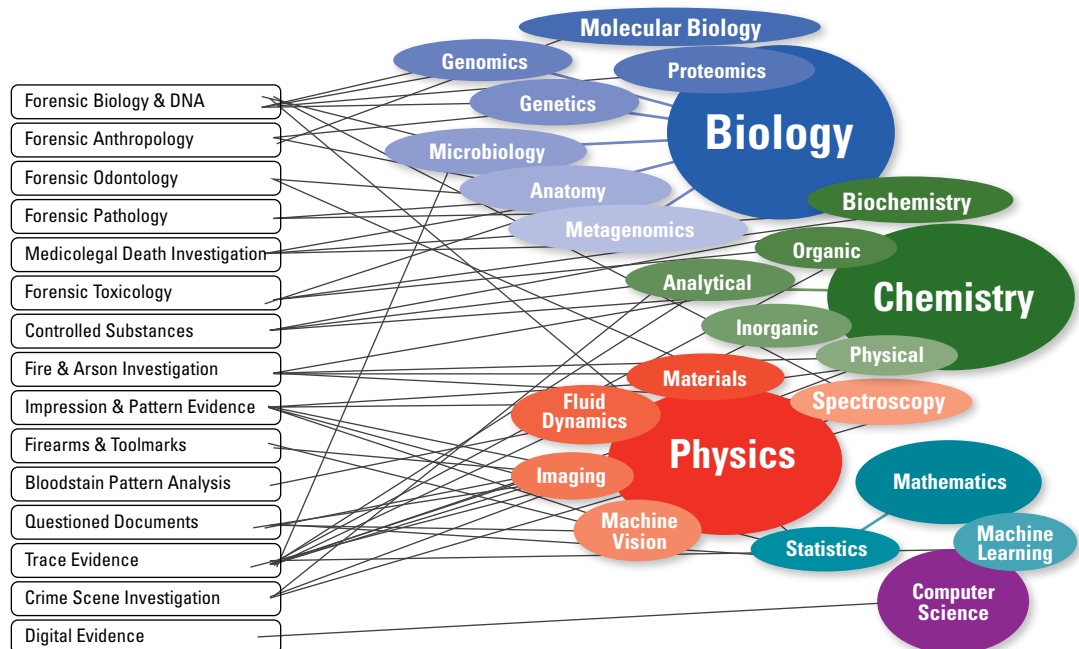
bachelor's or master's degree in chemistry or biology and then specialize in a specific area of study, such as toxicology, pathology, or DNA.⁷ These broad scientific disciplines give rise to many forensic subdisciplines that require specialized training and expertise (see exhibit 1).

Forensic scientists work in crime laboratories, police departments, medical examiners' offices, academia,

and research labs. According to the Bureau of Justice Statistics, publicly funded crime labs employed 14,300 full-time forensic personnel in 2014.⁸ In the same year, these labs received an estimated 3.8 million forensic requests, 3.6 million of which they completed. At the end of 2014, publicly funded crime labs had an estimated backlog of 570,100 requests for forensic services, and 38 percent of these labs outsourced one or more types of services.⁹

The Bureau of Labor Statistics projects that, between 2014 and 2024, there will be a 27 percent increase in open positions for forensic science technicians.¹⁰ These data and projections indicate a significant need to produce more forensic scientists over the next decade to develop highly discriminating, accurate, reliable, cost-effective, and rapid methods for the identification, analysis, and interpretation of physical evidence. Due to the inherent nature of the forensic sciences and the broad scope and depth of disciplines needed to address various crime-related problems, we must employ research, development, and technology in all areas of science and engineering.

Exhibit 1. Most Common Forensic Disciplines



What Is STEM?

The acronym STEM refers to science, technology, engineering, and math. First introduced by the National Science Foundation in the late 1990s and officially accepted in 2000,¹¹ STEM embodies the interrelatedness of the four disciplines as they relate to education.¹² It represents an integrative curriculum that incorporates the 21st-century skills needed for the jobs of the future, such as problem-solving, innovation, and teamwork.¹³ Over the past decade, STEM has evolved to refer not only to an integrative teaching strategy but also to a policy response and priority of K-12 school districts, federal science agencies, and higher education institutions. STEM generally includes the physical sciences (physics, math, and chemistry), life sciences (biology, anatomy, botany, and anthropology), engineering, and technology. Some federal agencies, such as the National Science Foundation, have a broad view of STEM and include the social and behavioral sciences (psychology and sociology). Other organizations also include architecture, medical sciences, and computer sciences.

In 2007, the groundbreaking report *Rising Above the Gathering Storm* highlighted the importance of STEM and its vital relation to U.S. global competitiveness, national security, and scientific literacy.¹⁴ Since then, there has been continued concern about the steady decline of U.S. dominance in science and engineering. Additional concerns regarding mediocre U.S. performance in science and math compared with other countries, low STEM interest among K-12 students, STEM achievement gaps between racial

and ethnic minorities and white students, and low representation of females and minorities in STEM majors and careers continue to shape federal and local science policy throughout the nation.

The Leaky Pipeline

The STEM sectors continue to face challenges in recruiting and sustaining individuals from diverse backgrounds.¹⁵ The “pipeline” metaphor refers to the accepted concept that to produce sufficient numbers of highly qualified STEM professionals for the workforce, there must be sufficient input of students starting in elementary school (see exhibit 2). The main segments of the STEM pipeline are:

- K-12 education: Students are exposed to STEM concepts through formal and informal activities.
- Undergraduate education: Students major in a broad scientific discipline.
- Graduate education: Students specialize in or master a specific field within STEM that involves conducting and publishing research.
- Career: Students are successfully placed into STEM careers.

There are many points along this pipeline where students exit for various reasons — a phenomenon generally known as the “leaky pipeline.”¹⁶ This is particularly true for females and underrepresented minorities, including African Americans, Hispanics/Latinos, Alaska Natives, American Indians, Asians/Pacific Islanders, and Native Hawaiians. (See sidebar, “Why So Few?”) This analogy suggests that there

Exhibit 2. The “Leaky Pipeline”



Why So Few?

There are several reasons for the underrepresentation of women and racial and ethnic minorities in STEM majors and occupations.¹ These reasons vary based on educational level, scientific discipline, and stage within the STEM pipeline. This lack of representation is not due to lack of ability or interest. Instead, it is primarily due to discouragement at every juncture along the educational and career development pathway, as documented in a 2010 survey conducted by the Bayer Corporation.²

At the K-12 level, it is in the form of teachers who discourage students from diverse backgrounds on the basis of preconceptions and implicit bias. Students at this level are also discouraged by negative stereotypes and images in printed media and textbooks that exclude them and make them feel like they are not worthy of scientific pursuits.³ At the undergraduate and graduate levels, discouragement comes from faculty who act as gatekeepers, and hostile department and campus cultures that lead to feelings of inadequacy and loneliness, which are described by the “solo status” and “imposter syndrome” constructs.⁴ At the professional level, the discouragement is from the often hostile culture in the workplace, particularly in the physical sciences and engineering.⁵

Women of color in STEM are significantly affected, as documented in the report *The Double Bind: The Price of Being a Minority Woman in Science*.⁶ Moreover, since STEM professions often pay more than non-STEM-related jobs, the STEM enterprise is viewed as a means of economic parity for many students who are not only underrepresented in STEM but are also of low socioeconomic status.⁷ Coupled with the fact that many minority and low-income students come from school districts with inadequate science education resources that limit their future aspirations, these students often become discouraged from scientific pursuits. This leads to a limited pool of STEM talent from which the forensic sciences can draw to solve criminal justice problems.

Notes

1. Catherine Hill, Christianne Corbett, and Andresse St. Rose, *Why So Few? Women in Science, Technology, Engineering, and Mathematics* (Washington, DC: American Association of University Women, 2010); and National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads* (Washington, DC: The National Academies Press, 2011).
2. Bayer Corporation, *Bayer Facts of Science Education XIV: Female and Minority Chemists and Chemical Engineers Speak about Diversity and Underrepresentation in STEM* (2010).
3. Bayer Corporation, *U.S. Women and Minority Scientists Discouraged from Pursuing STEM Careers, National Survey Shows* (2010), Press release, Bayer Facts of Science Education.
4. Bayer Corporation, “Bayer Facts of Science Education XV: A View from the Gatekeepers — STEM Department Chairs at America's Top 200 Research Universities on Female and Underrepresented Minority Undergraduate STEM Students,” *Journal of Science Education and Technology* 21 no. 3 (2012): 317-324, doi:10.1007/s10956-012-9364-1; and Catherine Good, Aneeta Rattan, and Carol S. Dweck, “Why Do Women Opt Out? Sense of Belonging and Women's Representation in Mathematics,” *Journal of Personality and Social Psychology* 102 (2012): 700-717, doi:10.1037/a0026659.
5. Bayer Corporation, *Bayer Facts of Science Education XIV: Female and Minority Chemists and Chemical Engineers Speak about Diversity and Underrepresentation in STEM* (2010).

6. Shirley Mahaley Malcom, Paula Quick Hall, and Janet Welsh Brown, *The Double Bind: The Price of Being a Minority Woman in Science* (Washington, DC: American Association for the Advancement of Science, 1976).
7. Anthony Carnevale, Jeff Strohl, and Michele Melton, *What's It Worth? The Economic Value of College Majors* (Washington, DC: Georgetown University Center on Education and the Workforce, 2011).

should be mechanisms in place to support and sustain students throughout their educational pathway.¹⁷

The pivotal report *Expanding Underrepresented Minority Participation: America's Science and Technology Talent at the Crossroads* chronicled the challenges of filling and sustaining the STEM pipeline and the impact of the lack of females and racial and ethnic minorities in the STEM workforce.¹⁸ According to the report, the U.S. STEM labor market is projected to grow faster than any other sector over the next decade, and participation by females and racial and ethnic minorities is not only a national priority but is critical to maintaining U.S. global competitiveness in technologically based sectors.

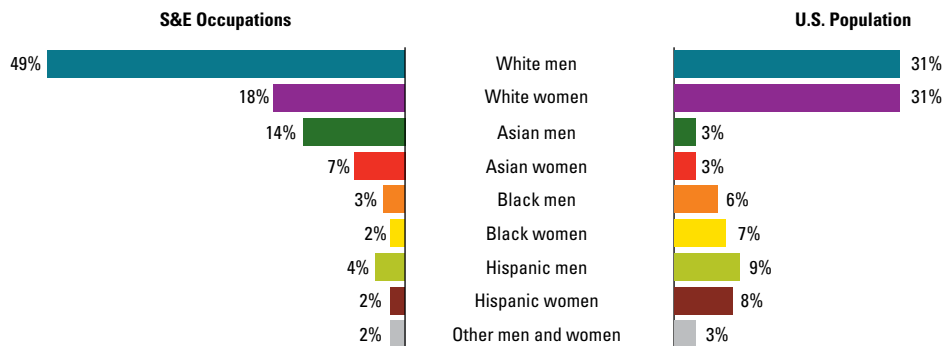
The 2010 census indicates that racial and ethnic minorities are the fastest growing segment of the U.S. population, and projections indicate that, by the year 2044, more than half of all Americans will belong to a minority group.¹⁹ However, these groups continue to be underrepresented in STEM fields (see exhibit

3). According to the National Science Foundation, women represent approximately 51 percent of the total population, but they represent only about 30 percent of science and engineering fields.²⁰ Within the science and engineering fields, representation of women continues to vary greatly, with approximately 70 percent in psychology and 18 percent in computer sciences.²¹

Additionally, Hispanics and African Americans represent 17 percent and 13 percent of the total population, respectively, but they represent only 6 percent and 5 percent of science and engineering fields.²² A wide gap in educational attainment continues between underrepresented minorities and their white and Asian counterparts, who consistently have higher representation in science and engineering fields than they do in the U.S. population.

Additional data from the National Center for Science and Engineering Statistics indicate that while women continue to see strides in the life and social sciences,

Exhibit 3. Science and Engineering Occupations by Race and Gender for 2015, Compared with the Total U.S. Population



Source: Adapted from National Science Foundation (NSF), National Center for Science and Engineering Statistics, *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2015*, Special Report NSF 15-311 (Arlington, VA: NSF, 2017), <http://www.nsf.gov/statistics/wmpd>.

It is well documented that diversity in STEM drives innovation and discovery, expands the questions that can be probed, and harnesses unique perspectives and skill sets.

they remain significantly underrepresented in the physical and engineering sciences.²³

In 2018, 2.4 million STEM-related jobs will need to be filled.²⁴ Will we be able to meet this growing demand for STEM talent? By diversifying the STEM pipeline, we will be able to draw on the brainpower and talent of segments of the population that have been historically discouraged from scientific enterprise. This will allow us to expand the problems and issues that can be addressed and the questions that can be asked. Research indicates that to improve diversity in STEM fields, from which forensic professionals are drawn, there must be concerted and intentional efforts to attract students by building pathways to STEM careers.²⁵ We know that underrepresentation in STEM careers is a direct result of lack of diversity in STEM majors.²⁶ We also know that efforts must start early in the K-12 years and must incorporate active learning and guided inquiry.²⁷ By focusing on closing key transition gaps between middle school, high school, college, and graduate school, we can retain and support more students, particularly those from diverse backgrounds. Without a sustained and highly qualified STEM workforce to undergird the forensic sciences, the United States will not be able to compete globally or provide innovative solutions to reduce crime and ensure public safety.

NIJ's Strategic Diversity and Inclusion Initiative

As the lead agency for forensic science research and development and programs dedicated to reducing backlogs of evidence in the nation's

forensic laboratories, NIJ's Office of Investigative and Forensic Sciences (OIFS) relies on the knowledge and expertise of a vast array of scientists, forensic practitioners, and criminal justice professionals to strengthen the forensic sciences. OIFS recognizes the need to enhance diversity in the forensic sciences and has undertaken a strategic planning process focused on expanding the pool of diverse talent in the various forensic science disciplines, particularly grant applicants, peer reviewers, and graduate research fellows. This strategic planning process includes three primary areas: assessment, outreach and engagement, and sustainability.

Assessment

To determine the state of awareness and to share diversity goals and planning efforts, NIJ has been participating in a series of workshops focused on the importance of diversity and inclusion for science organizations and how it affects everyday work, particularly with stakeholders. NIJ has also been evaluating the available demographic data on peer reviewers, principal investigators, grant applicants, and graduate fellows — data that will help NIJ determine areas of opportunity to focus on diversity efforts.

Outreach and engagement

Over the past year, NIJ has worked to expand awareness of the agency to the broader scientific and research communities. For example, NIJ has developed and implemented marketing strategies to expand communications to larger audiences of underrepresented students and professionals. These efforts include collaborating with professional scientific organizations with diverse membership profiles to share opportunities for research and development grants, peer reviewing, and graduate fellowships. Many of the professional scientific organizations — including the American Association for the Advancement of Science (AAAS), the Consortium of Social Science Associations, the National Society of Black Engineers, and the American Chemical Society — have memberships in the thousands and serve as conduits for information for potential candidates who were not being reached.²⁸

To reach a broad range of scientific disciplines, racial and ethnic backgrounds, and educational levels, NIJ partnered with the White House Initiative on Historically Black Colleges and Universities to facilitate two webinars and share opportunities for graduate student and faculty researchers.²⁹ As a result of this strategic collaboration, NIJ was invited to serve on an “Education and Justice” panel at the 2016 Historically Black Colleges and Universities Week Conference and discuss opportunities in forensic science and criminal justice with undergraduate and graduate students and faculty from around the country.³⁰ The White House Initiative has a stakeholder database of more than 4,000 students, faculty, and administrators involved in all areas of STEM and the social and behavioral sciences. These types of partnerships enable NIJ to reach broader and more diverse audiences in the higher education, research, and scientific communities.

NIJ has also expanded its outreach and engagement efforts by participating in conferences that target diverse populations in STEM. Over the past year, NIJ has participated in conferences for the Society for Advancing Chicanos/Hispanics and Native Americans in Science, the AAAS, the National Organization of Black Chemists and Chemical Engineers,³¹ and the American Indian Science and Engineering Society. NIJ also presented at the 2017 Emerging Researchers National Conference in STEM, which is sponsored by the AAAS and the National Science Foundation;

it included approximately 1,000 undergraduate and graduate student researchers of color from 10 National Science Foundation research programs.

Participation in these types of events has increased awareness and helped lift the science of NIJ to broader and more scientifically diverse audiences. These efforts will also help expand the pool of potential peer reviewers who will be called on to serve on grant review panels, which is the primary mechanism that guides award funding decisions.

Sustainability

NIJ has several research initiatives aimed at building the STEM pipeline and creating pathways for students and early researchers from diverse backgrounds to advance scientific knowledge to solve criminal justice problems. (See sidebar, “Supporting Innovative Research to Address Complex Criminal Justice Problems.”) These include the Graduate Research Fellowship in STEM (GRF-STEM) and the Research Assistantship Program (RAP). Both programs support STEM degree attainment and expand the talent pool in scientific disciplines engaged in criminal justice and forensics-related research.

For decades, the Graduate Research Fellowship Program has been NIJ’s primary vehicle for supporting graduate research aimed at providing solutions for problems related to forensic science and criminal justice policy and practice. The GRF-STEM Program

Supporting Innovative Research to Address Complex Criminal Justice Problems

In 2016, Candice Bridge at the University of Florida earned a research and development grant from NIJ to improve rape investigation methods in cases where DNA is limited or nonexistent. Her lab will analyze lubricants and condoms and build a database that will provide another potential connection between the perpetrator and the victim. This work will hopefully help to identify and convict more rapists.

Bridge obtained her Ph.D. in forensic chemistry at age 25 and is one of the first African American females to teach chemistry at her alma mater, Howard University. By funding this work, which will support one postdoctoral fellow and one doctoral student, NIJ is not only helping to advance the careers of early STEM faculty and researchers but is also creating a pathway for students from diverse backgrounds and scientific disciplines to make vital contributions to the forensic sciences.

provides awards to accredited academic institutions to support graduate research leading to doctoral degrees in topic areas that are relevant to ensuring public safety, preventing and controlling crime, and ensuring the fair and impartial administration of criminal justice in the United States. This program supports research in a broad array of scientific disciplines, including the life sciences, physical sciences, math, computer sciences, and engineering.

Exhibit 4 shows demographics for the graduate fellowships awarded in FY 2016 and indicates support of various scientific fields that correspond to multiple forensic disciplines. Some of the research studies that were awarded in FY 2016 include:

- Improved detection of kratom alkaloids in forensic toxicology.
- A mechanism-based forensic investigation into the post-mortem redistribution of morphine.
- Developing forensic epigenomic age-estimation tools for diverse populations.
- New concept for fingerprint analysis: bioaffinity-based systems utilizing amino acids.
- Nanostructural characterization of ballistic fiber degradation.
- Characterization of personal and condom lubricants using DART-TOFMS and comprehensive GC-MS.
- Nanoparticles for chemical imaging of latent fingerprints.³²

By supporting graduate student research in these areas, NIJ addresses some of the persistent barriers to completing STEM doctoral degrees — lack of funding and research opportunities. Moreover, NIJ is strengthening forensic science policy and practice by advancing technology, improving analytical sensitivity and selection, and enhancing processes to accurately identify crime scene evidence.

RAP has historically supported students in the social and behavioral sciences to address issues related to violence, victimization, corrections, and sexual assault. NIJ recently expanded the program to include support for students in STEM fields, allowing the Institute

to support student development and research in additional areas related to science and engineering, including digital forensics and multimedia analysis, data science applied to crime justice, body armor for female law enforcement officers, geospatial and crime mapping, and forensic analyses on sexual assaults. RAP involves an onsite residency at NIJ for a minimum of 20 hours a week. The benefits of this residency include interacting with criminal justice researchers who can serve as mentors, provide authentic career advice, and help students develop the skills needed to be successful in the workforce.

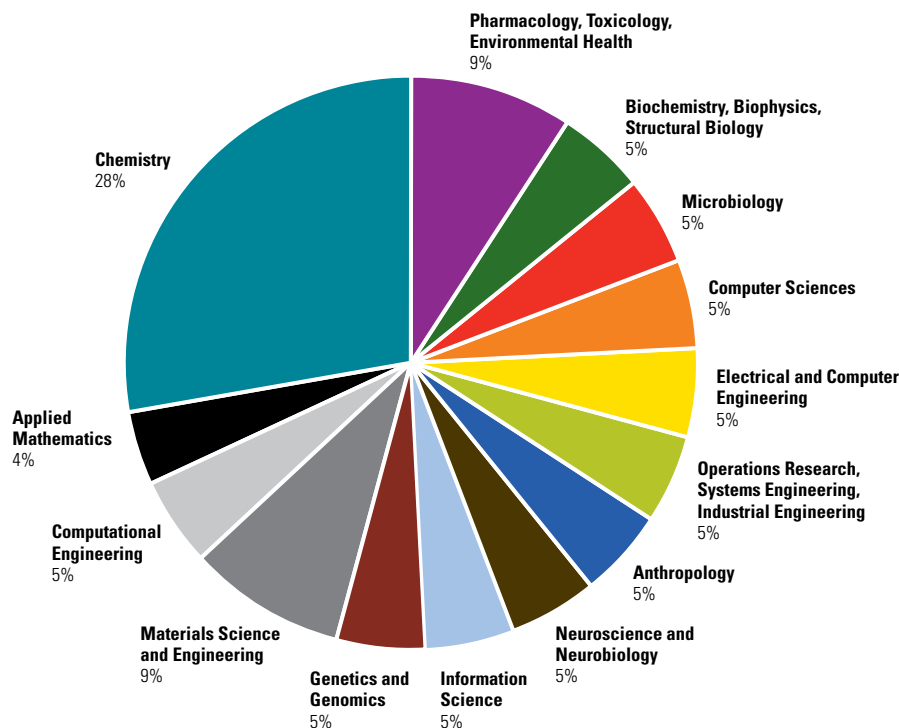
As NIJ develops and implements its diversity and inclusion strategic initiative, it will continue to engage, collaborate, and partner with stakeholders throughout the scientific, educational, and research communities. For example, NIJ has committed to serve an active role on the American Academy of Forensic Sciences Diversity Committee to help broaden the pool of students and practitioners in the forensic sciences. The NIJ Diversity Working Group is also actively developing and implementing the strategic diversity initiative and will work with leadership to advance these efforts.

Diversifying the Future

As the forensic sciences continue to evolve, it is imperative that we value and leverage all segments of the population to tackle complex criminal justice problems. It is well documented that diversity in STEM drives innovation and discovery, expands the questions that can be probed, and harnesses unique perspectives and skill sets. While diversity in gender, race, and ethnicity is critical in broadening the pool of forensic and criminal justice researchers, diversity in scientific disciplines is equally important as we seek to take advantage of more interdisciplinary approaches to problem-solving.

NIJ remains committed to engaging the best and brightest talent to assist with advancing scientific knowledge for criminal justice purposes. To achieve this goal, we must cast a wide net and leverage all of the available human capital. These efforts are critical to attracting and sustaining STEM talent to

Exhibit 4. FY 2016 Graduate Research Fellowship Attributes



address both current and future needs in the forensic sciences.

Learn more about the Research Assistantship Program at NIJ.ojp.gov, keyword: rap.

About the Authors

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For More Information

Learn more about the Graduate Research Fellowship in STEM at NIJ.ojp.gov, keyword: fellowship.

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